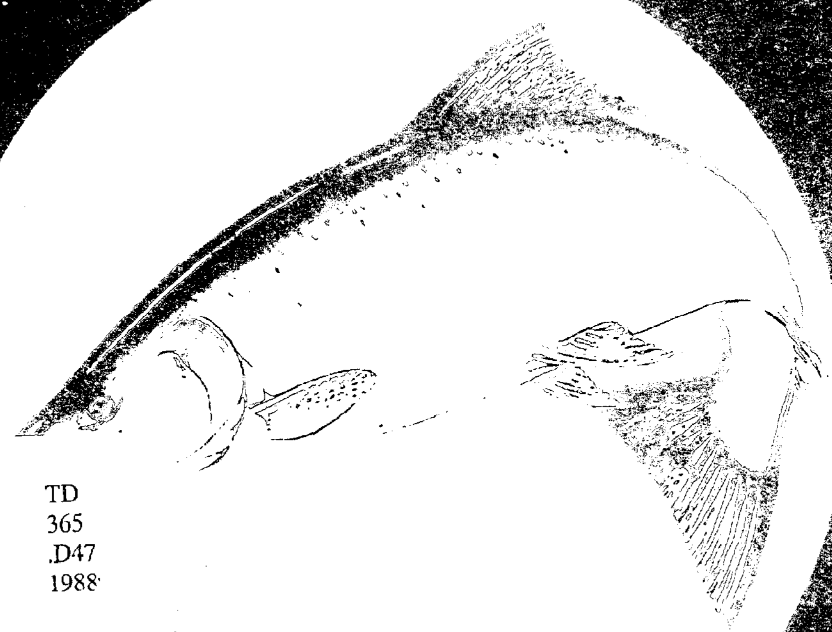
Design of Studies for Development of Bonneville Power Administration Fish and Wildlife Mitigation Accounting Policy

Volume 1 - Summary Report

U.S. Department of Energy
Bonneville Power Administration
Division of Fish & Wildlife

Resources for the Future

August 1988



Final
Report
1988

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

For copies of this report, write to:

Bonneville Power Administration
Division of Fish and Wildlife - PJ
P.O. Box 3621
Portland, OR 97208

TD365 .D47 1988 v.1

DESIGN OF STUDIES FOR DEVELOPMENT OF BONNEVILLE POWER ADMINISTRATION FISH AND WILDLIFE MITIGATION ACCOUNTING POLICY

Phase II Final Report

Volume 1: Summary Report

Prepared By

Allen V. Kneese,
Danny C. Lee,
Charles M. Paulsen, and
Walter O. Spofford, Jr.
Resources for the Future
1616 P Street, NW
Washington, DC 20036

Prepared For

Stanley Detering, Project Manager
U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, Oregon 97208
Project No. 85-87
Contract No. DE-AC79-85BP24238

August 1988

Table of Contents

Design of Studies for Development of BPA Fish and Wildlife
Mitigation Accounting Policy

Volume 1: Summary Report

Title	Page
Introduction	1
Historical Background...	2
Figure 1: The Columbia River Basin.......................	4
The RFF Research Program....................................	6
Part I: Modeling the Salmon and Steelhead Fisheries of the Columbia River Basin......................................	9
Systems Analysis and the Fish and Wildlife Program............	9
Figure 2: Information Flows Among Management, Modeling and Research..	11
Special Challenges in Modeling the Columbia River Basin.......	13
A Proposed Biological Modeling Approach......................	14
Figure 3: Hierarchical Modeling Structure for Hypothetical System Which Includes Three Stocks of Interest.........	15
Life-stanza Models..	17
Table 1: Outline of Major Features of Proposed Life-Stanza Models...	18
Juvenile Production..	20
Modeling the Outmigration....................................	21
Early Marine Survival and Growth.............................	21
The Late Ocean Period..	22
Modeling Upstream Migration..................................	23
Models and Monitoring..	23
Relevance to the Power Planning Council's Modeling Effort.....	24
Conclusions..	26
Part II: Models for Cost Effectiveness Analysis....................	27
Background...	27
Overview of the Economic-Ecological Simulation Model..........	28
Figure 4: Schematic Diagram of the Economic-Ecologic Simulation Model for Cost-Effectiveness Analyses.......	29

Table of contents (continued)

Hydrosystem Simulation Model................................ 30
Fish Production and Migration Simulation Model................ 32
Cost Evaluation Model.. 33
Economic Criterion and Costs................................. 33
Approaches to the Least-Cost Analysis........................ 35

Part III: Ocean Fisheries Management.............................. 40

Background... 40
How to Model the Ocean Fishery............................... 43
Valuing Changes in Salmon Stocks............................. 46
Determination of Economic Impacts............................ 47
Concluding Comments.. 48

Comments on the Phase II Draft Report............................. 49

Justification for Further Research........................... 49
Ecological Modeling Issues................................... 50
Understanding the Economics.................................. 52

Appendix A: Attendance List for Public Discussions on the Draft Report 54

Appendix B: Written Comments on the Phase II Draft Report........... 56

Appendix C: Phase II Personnel and their Main Contributions
to the Final Report.................................. 81

INTRODUCTION

Congressional passage of the Pacific Northwest Electric Power Planning and Conservation Act (Regional Act) in 1980 ushered in a new era in natural resource conservation in the Pacific Northwest. A significant feature of the Regional Act was that it established a unique interstate compact, commonly called the Northwest Power Planning Council (Council). Appointed by the Governors of their respective states, two members from each northwestern state--Oregon, Washington, Idaho, and Montana--compose the Council. The Council is charged with developing programs for (1) regional power planning, (2) electricity conservation, and (3) mitigating the effects of hydropower development and operation on fish and wildlife in the Columbia River Basin.

While the responsibility for power, conservation, and mitigation program planning lies with the Council, the responsibility for implementing many of the program measures lies with the Bonneville Power Administration (BPA) and other federal agencies with hydro or power responsibilities in the region: the Corps of Engineers, the Bureau of Reclamation, and the Federal Energy Regulatory Commission. Under the terms of the Regional Act, BPA is required to use its funding authorities to support measures designed, "to protect, mitigate, and enhance fish and wildlife to the extent affected by the development and operation of any hydroelectric project of the Columbia River and its tributaries" (Sec. 4(h)(10)(A)). Through this mechanism, the costs of mitigating federal hydroelectric development and operation within the Columbia River Basin are to be borne by electrical consumers which purchase power from BPA.

In the years since the passage of the Regional Act, the BPA, the Council, and numerous national and regional agencies, both public and private, have mounted an impressive collaborative effort to protect and enhance the fish and wildlife of the Columbia River Basin and to mitigate damages caused by hydroelectric development and operation. Indeed, estimated BPA costs in this endeavor (including direct expenditures, foregone power revenues, and repayments to the U.S. treasury on behalf of other federal agencies) totaled about $375 million for the period 1983 to 1986. Many of the mitigation measures enacted thus far have proceeded without the benefit of much formal analysis, but in most instances informed judgment has established that such measures are justified.

As the mitigation prescribed by the Regional Act proceeds, the incremental costs of corrective measures to lessen the environmental impacts of the hydroelectric system are expected to increase and difficult questions to arise about the costs, effectiveness, and justification of alternative measures and their systemwide implications. It was deemed prudent by the BPA to anticipate this situation by launching a forward-looking research program aimed at providing methodological tools and data suitable for estimating the productivity and cost implications of mitigation alternatives in a timely manner with state-of-the-art accuracy. In this spirit, Resources for the Future (RFF) agreed at the request of the BPA to develop a research program which would provide an analytical system designed to assist the BPA Administrator and other interested and responsible parties in evaluating the ecological and economic aspects of alternative protection, enhancement, and mitigation measures.

Historical Background

The events leading up to the fish and wildlife provisions of the Regional Act began in the middle and late 1930s when several large dams and powerhouses were created on the main stem of the Columbia River, partly for the purpose of providing employment and other economic stimuli during the Great Depression. The first major dam, Rock Island, a Public Utilities District dam, was completed in 1933, and the much larger federal Bonneville and Grand Coulee Dams in 1938 and 1941, respectively. Toward the end of this early history of hydro development on the Columbia River, it became apparent that an agency would be needed to transmit and market the large amounts of hydroelectricity that would soon become available. To fulfill this need, the Congress passed the Bonneville Project Act in 1937 which created the "temporary" Bonneville Power Administration. Fortuitously, a large market for electricity developed quickly, primarily in the electrometallurgical industries that produced aluminum for aircraft construction during World War II. After the war electrical demand in the Pacific Northwest grew steadily and fast until very recently, and hydropower development occurred simultaneously on a very large scale.

The system of federal dams in the region came to be known as the Federal Columbia River Power System (FCRPS). At present it consists of 31 projects with total installed capacity of 19,350 megawatts and over 20 million acre-feet of storage capacity. In addition, there are large public and private utility hydroelectric dams and federal and state dams for flood control. The provided map illustrates the location of major dams within the Columbia River Basin (Figure 1).

Though the FCRPS and other hydroelectric projects provide inexpensive electric power to the region, they also interfere with anadromous fish reproduction and migration. This has led to large losses in potential fish production. But there have been other major sources of such losses, many of which historically preceded hydrosystem development. Logging, mining, agricultural practices and overfishing have hindered anadromous fish production for many years. A large ocean fishery, which developed in time roughly corresponding to the great dam-building era on the Columbia, continues to harvest a large proportion of salmon produced in the Columbia River Basin.

Adding to these factors, a severe drought in the late 1970's and the occurrence of unfavorable ocean conditions reduced fish runs to historical minimums. While the circumstances leading to the passage of the Regional Act stemmed primarily from other sources, the Congress was prompted by environmental concerns, particularly for anadromous fish, to include the following language in the Act:

> 4.(h)(5) The Council shall develop a program on the basis of such recommendations, supporting documents, and views and information obtained through public comments and participation, and consultation with the agencies, tribes, and customers referred to in subparagraph (A) of paragraph (4). The program shall consist of measures to protect, mitigate, and enhance fish and wildlife affected by the development, operation, and management of such facilities while assuring the Pacific Northwest an adequate, efficient, economical, and reliable power supply. Enhancement measures shall be included in the program to the extent such measures are designed to achieve improved protection and mitigation.
>
> 4.(h)(6) The Council shall include in the program measures which it determines, on the basis set forth in paragraph (5),

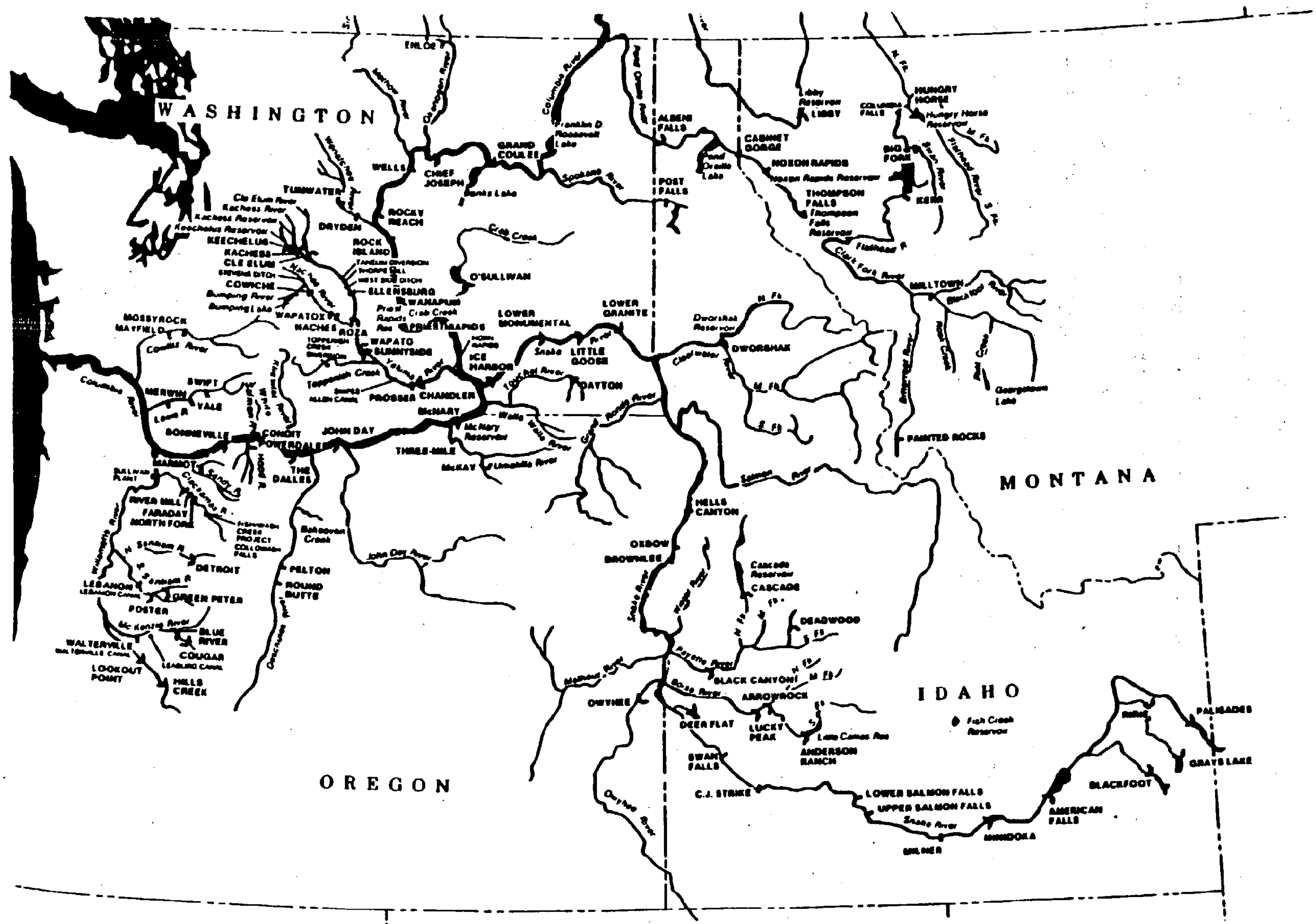


Figure 1. The Columbia River Basin

will--(A) complement the existing and future activities of the Federal and the region's State fish and wildlife agencies and appropriate Indian tribes; (B) be based on, and supported by, the best available scientific knowledge; (C) utilize, where equally effective means of achieving the same sound biological objective exists, the alternative with the minimum economic cost; (D) be consistent with the legal rights of appropriate Indian tribes in the region; and (E) in the case of anadromous fish--(i) provide for improved survival of such fish at hydroelectric facilities located on the Columbia River System; and (ii) provide flows of sufficient quality and quantity between such facilities to improve production, migration, and survival of such fish as necessary to meet sound biological objectives.

Having followed the procedures specified by the Regional Act, the Council adopted its original Fish and Wildlife Program late in 1982. The initial Program contained a variety of mitigation measures, including the installation of bypass facilities to guide migrating young salmon around powerhouse turbines at major dams in the Columbia and Snake Rivers and a special allocation of water for fish, called the water budget. Federal project officers and regulators annually provide the fish and wildlife agencies and the tribes with a total water budget of 4.64 million acre-feet to be used at their discretion between April 15 and June 15 to augment flows normally provided for other purposes, including hydroelectric generation, navigation, and flood control. These enhanced flows, which aid the passage of juvenile fish downstream, are timed in such a way as to maximize their effect. In dryer years when flows fall below average, such as occurred in 1987, providing water budget flows can result in substantial losses in revenue to power producers.

The Fish and Wildlife Program was amended in 1984 and again in 1987 and emphasis remains on the area of the Columbia River Basin upstream from Bonneville Dam. The greatest losses of fish runs have been in the upper Columbia and Snake River areas, while most of the mitigation prior to the Regional Act involved increased hatchery production in the lower basin. The Council has also initiated a process of subbasin planning with priority given to the areas above Bonneville Dam. However, the Council recognizes the need for systemwide integration. Indeed, one of the more important features of the Regional Act is that it specifies that a systemwide approach be taken in the planning and implementation of mitigation efforts.

In the 1987 Program amendments, the Council established an interim objective of doubling the average annual production of adult Pacific salmon and steelhead trout which they presently estimate to be about 2.5 million fish. This total includes fish that are caught at sea and adult fish returning to the mouth of the Columbia River. The Council has not set goals or objectives for specific stocks and subbasins; these products are expected from future planning.

The RFF Research Program

The research program proposed by RFF was intended to be completed in three phases. Phase I, jointly sponsored by the BPA and RFF, was designed to identify economic and related research issues to be pursued in later stages of the research program. A document reporting on Phase I was delivered to BPA in mid-1984. The Phase II research was aimed at providing a comprehensive design of the research program--including development of needed methodologies, identification of data needs and potential sources, and a plan for the program's execution. The bulk of the actual research now contemplated is to be conducted in Phase III, although the research planning has involved considerable research in its own right.

The work plan for Phase II, agreed to by RFF and BPA, specified the following tasks:

Task 1: Investigate the feasibility of, and to propose a plan for development of a system model which would provide capability to estimate loss in fish productivity attributable to development and operation of the hydroelectric system and individual hydroelectric projects and would include the hydrologic, ecologic, and economic components of the Columbia River system, including using suitable (as determined by the contractor) components of existing models.

a) Assess the utility of existing Columbia Basin and Pacific Northwest fish harvest, juvenile migration, and habitat potential models for development of BPA fish and wildlife mitigation accounting procedure and policy. Documentation for the models ... will be obtained by the contractor.

b) Prepare a plan for model development which recognizes the need to include components in a system model which would allow simulating the fish production effects of:

i) historic, existing and prospective levels of natural habitat productivity,

ii) alternative harvest management strategies and practice, and

iii) alternative protection, mitigation strategies and practice, and including long-term change in the amount and location of water diversions or instream flow regime, for the purpose of comparing the cost-effectiveness of such alternatives.

Task 2: Design a study to assess alternative procedures for allocating responsibility for loss in fish productivity:

a) to the hydroelectric purpose of federal hydroprojects,

b) between federal and non-federal hydroelectric projects, and

c) to systemwide loss caused by hydroelectric system development and operation, but not attributable to project(s) of any single owner.

Task 3: Inventory available monitoring and accounting options and evaluate their suitability to the objective of formulating a system for measuring mitigation progress, to include:

a) approaches to monitor changes in production of smolts and adult anadromous fish, and

b) study of methods to statistically adjust results of monitoring for random variations and other perturbations to fish production not caused by the hydroelectric system or mitigation efforts.

The Phase II research planning covered all aspects of the work plan but the emphasis placed on various components evolved as the RFF team delved into the nature of the problems to be addressed and as a result of ensuing developments within the region. Specifically, the Council's acceptance in 1986 of an estimate of the loss in fish production attributable to the hydroelectric system lessened the relative importance of developing analytical methods for this task. Most of the effort in Phase II was expended on Task I which (in abbreviated form) called for investigation of the feasibility of, and development of a plan for, a system model including the hydrologic, ecologic, and economic components of the Columbia River system. Where suitable, components of existing models were to be included. The primary motivation for developing such a model (or set of models) is to provide an analytical basis for estimating the biological and economic implications of alternative management strategies.

The necessary steps in developing an analytical system for the Columbia River system follow a natural progression. The first step in developing such a system is understanding the ecological relationships that are inherent within the fisheries. One can then begin to build mathematical models which quantitatively estimate the changes in fish production that might result from management actions. From there, if estimates of the economic costs of alternative management strategies can be made, tradeoffs among levels of fish production and cost can be examined. If the system permits it, advanced analytical techniques may allow one to determine which combination of measures will result in a given level of fish production at least cost.

While this progression from a ecological understanding to cost-effectiveness analyses is straightforward in concept, the complexities of the Columbia River system make the development of analytical methods far from simple in practice. The Phase II final report outlines the technical issues involved in developing an analytical system and proposes a program of research to address these issues. The report is presented in this summary report (Volume 1) and Volume 2 which consists of three technical reports: Part I, Modeling the Salmon and Steelhead Fisheries of the Columbia River Basin; Part II, Models for Cost-Effectiveness Analysis; and Part III, Ocean Fisheries Harvest Management. The following discussion briefly summarizes information given in each major section of Volume 2. In addition, a closing section concerning written comments received on the Phase II draft report is included.

PART I: MODELING THE SALMON AND STEELHEAD FISHERIES OF THE COLUMBIA RIVER BASIN

Systems Analysis and the Fish and Wildlife Program

The Fish and Wildlife Program adopted by the Northwest Power Planning Council represents a most remarkable and ambitious collaborative effort to protect, mitigate, and enhance the anadromous fish populations of the Columbia River Basin. The regional scope and immense probable cost of this effort demand that careful consideration be given to program management--the planning, coordination, and evaluation of measures called for within the Fish and Wildlife Program. The analytical tools which are needed to facilitate program management fall within the purview of systems analysis.

In simple terms, systems analysis can be defined as a body of theory and analytical techniques which are designed to assist policy makers in choosing among options. Two of the more useful tools of systems analysis are modeling, in which complex systems are represented by abstractions, and simulation, a process in which one tries to better understand system behavior and to anticipate potential impacts of management actions by constructing and experimenting with computer models. When used correctly, systems analysis can be a vital component of the decision-support system used in natural resource management. The role of systems analysis within the framework of the Fish and Wildlife Program is discussed in Volume 2, Part I. A clear understanding of the use of modeling to support management and research is needed before proceeding with model development.

One view of modeling is as an intermediary between resource management and research. Models provide a coherent way of summarizing information gained from past management experience and research, and presenting this knowledge in a usable fashion to resource managers and researchers. For long-term, regional resource allocation problems such as those in the Columbia Basin, it is important that the modeling process keep pace with changes in management philosophy and current understanding of the system. One must understand the dynamic nature of management and research, and the equally dynamic role that models must play.

This view of a dynamic relationship between modeling and components of management and research is depicted in Figure 2. Within the system illustrated therein, information is exchanged between components. The only static feature is the management goal. Goals involve implicit values and they are generally stated in ways that make them inherently non-quantifiable. For example, a goal might be "to improve the upriver salmon fisheries." Once defined, the management goal is the primary impetus for management, modeling, and research. The final objective is to have in place measures which serve the management goal. The components other than goal definition receive inputs from, and have explicit feedback loops associated with, one or more additional components. The nature of these components will change with time in response to new or updated information as it becomes available.

In order for this information system to work most effectively, all information pathways shown in the diagram must exist, and information transfer must take place in a timely manner. This is especially true of the feedback loops which pass through monitoring and evaluation and through model corroboration, a systematic process of comparing model structure and predictions to actual system behavior. Premature termination of an information loop can be a invitation to disaster. For example, a tempting shortcut might be to define a management goal, characterize the system involved, formulate a model, run simulations, plan a program of management measures based on model predictions, and implement the chosen measures. Such a strategy may suffice for a localized problem in which the system is reasonably well understood, but it is an imprudent strategy for a large, complex system such as the Columbia. It is unreasonable to assume that one will entirely "get it right the first time." Some measures will work better than expected, some worse, and some not at all. Disappointing or negative results from management actions should not be used simply as ammunition for sinking an ongoing modeling program. Rather, knowing that a certain measure performed poorly provides information that should be used to correct inaccurate models which can then be used for future analyses. In a similar fashion, a well-directed research program can be of immense benefit to the management effort by improving the predictive capabilities of the models.

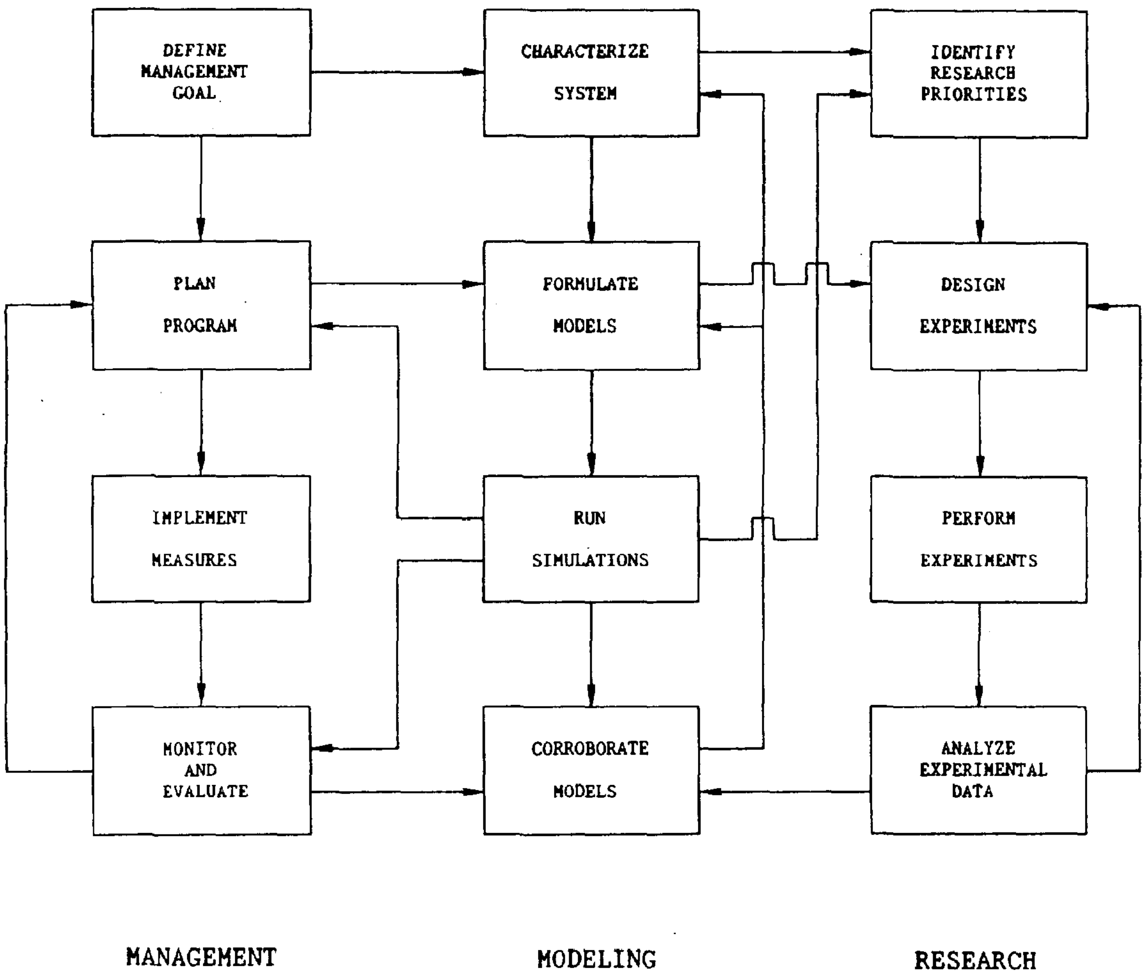


Figure 2 Information Flows Among Management, Modeling, and Research.

In regard to the Columbia River Basin Fish and Wildlife Program, three areas in which modeling and simulation could play pivotal roles include (1) program planning, (2) system monitoring, and (3) developing a research agenda. These three areas are obligate complements of one another. The system and subbasin planning process described in the 1987 Fish and Wildlife Program requires that the parties which define goals and objectives must also prescribe the measures needed to achieve them. In a system as complex as the Columbia, integration of subbasin plans is a formidable challenge. Also, ensuring program effectiveness requires adequate monitoring which can both identify effective mitigation efforts and measure progress towards a specified goal. All of these tasks share a common prerequisite--knowledge of the ecological processes at work within the basin--which calls for a sound research program. Such a research program should properly include both basic research and a provocative management strategy (adaptive management) which reduces uncertainty by treating management actions as experiments to provide information about the system which can then be used for more efficient management.

In Part I of Volume 2, the role of systems analysis and simulation models in addressing each of the above tasks is discussed. Basically, models serve as tools for integrating information, identifying uncertainties, and anticipating change. If models are to be used in the Columbia River system, it is clearly in the best interest of all parties concerned that the involved models represent the best available technologies and scientific understanding. Part I outlines an approach to modeling the population dynamics of salmon and steelhead from the Columbia River Basin with special reference to the influence of the hydroelectric system. As noted, the Phase II task assigned to RFF has been to consider the problem of modeling the Columbia River Basin, design a modeling program, and develop recommendations for research in Phase III--not to explicitly model the fisheries of the basin. Therefore, the heuristic models which are presented serve only as examples of technologies which could be employed in future modeling efforts.

Consistent with the broad scope identified in the work plan, the research planning presented in the Phase II final report spans the pertinent systems involved--ecological, hydrological, and economic. While

Part I deals primarily with modeling fish population dynamics, Part II of Volume 2 focuses upon hydrology and economics and the interrelationship among all three components. Extensions of the methods proposed in Part I to include costs are discussed in connection with the contents of Part II in the next major section of this summary report.

Special Challenges in Modeling the Columbia River Basin

In designing models of the Columbia River Basin fisheries, there are three major concerns that must be addressed: (1) the ecological complexity of the system, (2) pervasive uncertainties, and (3) the intended use of the models. The intricate and unique life histories of the many stocks (populations which are genetically, spatially, or behaviorally separated from other populations) within the Columbia add to system complexity and provide ample opportunity for anthropic influence through hydroelectric generation, harvest, irrigation, and environmental degradation. Also, despite a long history of fishery research on the salmonids of the Columbia River Basin, many important ecological processes or relationships remain poorly understood. For example, little is known about the major processes affecting survival and growth of juvenile salmon in the estuary and ocean, a component which may be crucial in determining the relative success of a stock. Even when processes are reasonably well understood, reliable parameter estimates remain elusive. This combination of complexity and uncertainty raises two problems for would-be modelers. The first is trying to understand the system well enough to construct a model and define reasonable parameters. The second is trying to strike a balance such that the models contain the detail necessary to characterize the system but are not so complex as to compromise their utility in planning and policy analysis.

The third major concern is related less to what is known about the system than to what questions might be asked of models. The concern is that models might be asked to address questions that are divergent in scope. To illustrate, one might ask two questions: (1) what is the impact of the water budget on run size, and (2) how will improving bypass facilities at Little Goose Dam affect smolt survival past the dam? The first question is clearly broader in scope than the second and has systemwide connotations. If separate models were designed to address these questions, the model designed to answer the second question would be narrower in scope and have a finer level of resolution. The dilemma is that if only a single model is to be built, then it must have the scope to answer the system-wide question and the resolution to answer the second, more site-specific question. Such a model would likely be so large and cumbersome that it would be of little use to fishery managers.

A Proposed Biological Modeling Approach

In order to tackle the complex problems posed by the Columbia system, we propose a hierarchical approach to modeling the biological aspects of the salmon and steelhead fisheries. Within this hierarchical structure, models are arranged according to the relative spatial and temporal extent of the system simulated by each model (scope). As the scope progressively increases, the level of resolution within the models decreases. This limits the overall size of the models so that they may fit on a micro- or mini-computer. Separate models of distinct periods in the salmonid life cycle (life stanzas) form the lowest level in the hierarchy, followed by models of the complete life cycle, and at the highest level, a system-level model(s) (Figure 3). Individual models within each level of the hierarchy have the capacity to work independently or in tandem. Each model is constructed such that outputs from one model can serve as inputs to other models. Conceptually, the components of one level collectively encompass the next level in the hierarchy. For example, the life stanzas collectively define the complete life cycle of a salmon population, while a collection of populations represent all stocks of interest within a defined system.

The primary reason for modeling life stanzas separately is to allow detailed representation and isolated analysis of each life stanza. Using this approach, one can address questions that vary in scope with a model or arrangement of models that operate at a relatively fine level of resolution. For example, the effect of fallback on upstream survival might be properly examined using a model which simulates only the upstream migration. If increasing the number of smolts passing Bonneville Dam is a key objective, one might analyze alternatives using the juvenile production

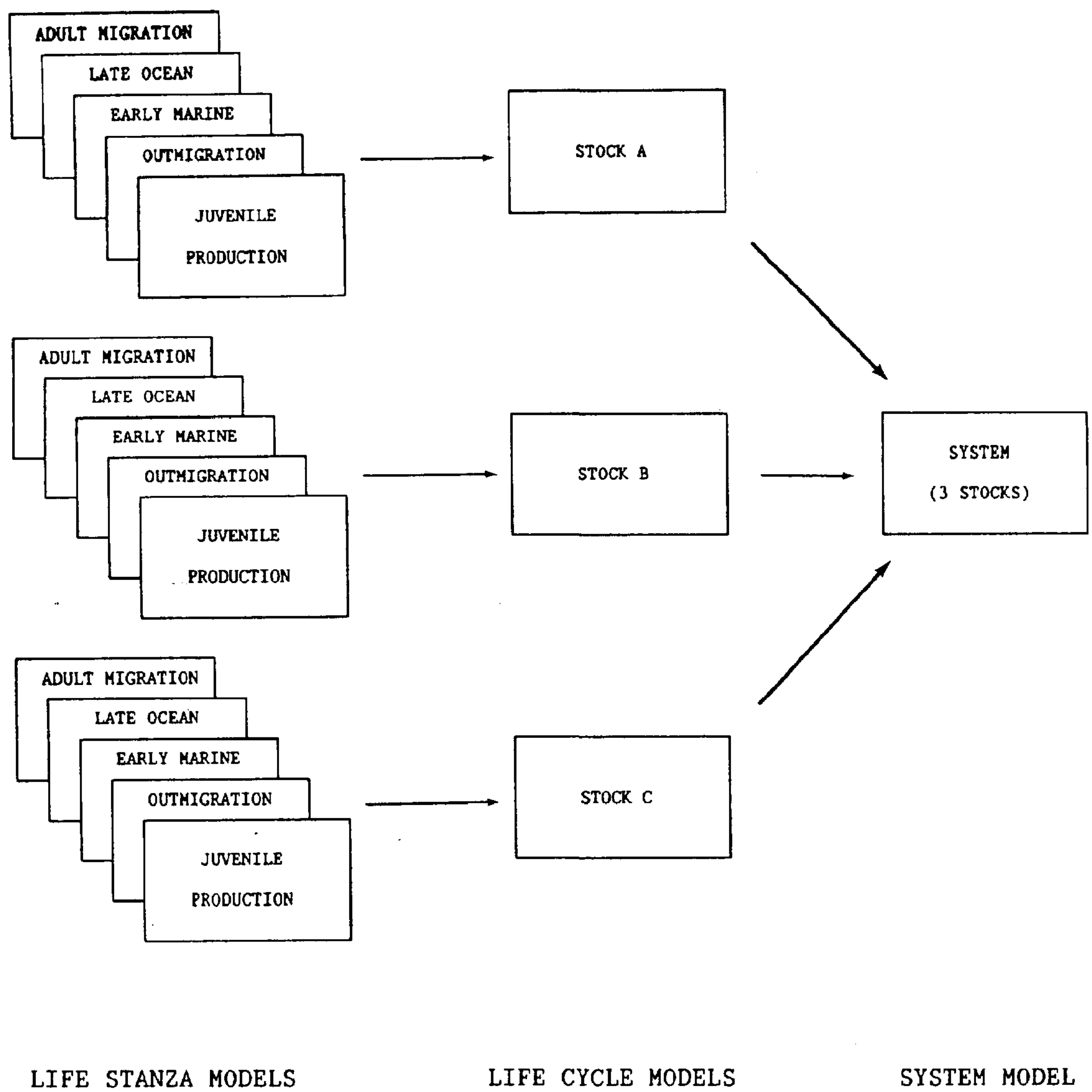


Figure 3 Hierarchical Modeling Structure for Hypothetical System Which Includes Three Stocks of Interest. Arrows point in the direction of increasing scope, decreasing resolution.

and downstream migration models with a hydrologic model in a tandem arrangement. In both examples, the modular structure provides the resolution and the scope necessary to examine the questions at hand without the burden of having to deal with the remainder of the system during the analyses.

Many times questions are asked that concern the complete life cycle. For example, is it feasible to have a sustainable, naturally reproducing population of spring chinook salmon in the Clearwater River Basin? It is possible to address such questions by linking life-stanza models together, but such an arrangement is cumbersome. Also, the level of resolution provided by the life-stanza models is likely unnecessary or inappropriate for population-level analyses. For this reason, life-cycle models are needed for the next level in the hierarchy which operates at a coarser level of resolution. The purpose of a life-cycle model is to simulate the complete life cycle of a particular salmon or steelhead stock.

In an analogous fashion, there are system-level questions to be addressed for which life-cycle models are inadequate. The intent of the Regional Act requires a systemwide approach that entails balancing the biological needs of many salmon and steelhead stocks with the often conflicting demands of those harvesting the fish, and of other users of the river system. Because of the temporal and spatial segregation of salmon and steelhead stocks within the basin, certain mitigation measures such as habitat improvement may be relatively stock-specific. Other, more systemwide actions such as the water budget and smolt transportation may benefit a variety of stocks. Both types of measures contribute to the overall goal of the Fish and Wildlife Program by increasing total run size, but a mechanism is needed to evaluate the tradeoffs in terms of costs and equity among systemwide and stock-specific actions. As an illustration, systemwide improvements in downstream passage at first might seem to be prohibitively expensive. However, the costs of passage improvements may compare favorably with the total costs of alternative investments in increasing the juvenile production of upstream stocks on a stock-by-stock basis to achieve similar results. Special concern should be given to actions which may benefit a certain stock(s) while being detrimental to others. For example, increasing hatchery production might lead to excessive harvest pressure on wild stocks, thereby prohibiting these stocks from rebuilding. Addressing questions such as these requires a system model. Such a model does not need the resolution of the life-cycle or life-stanza models, but it does need to faithfully represent the basic ecological relationships inherent in the system.

A primary requirement of model construction is that logical consistency must be maintained across all levels of the hierarchy. In other words, the behavior of a model in any given level should be compatible with the behavior of the more detailed models at all lower levels of the hierarchy. In order to insure consistency, construction of models within a given level is constrained by both higher and lower level considerations. Guidelines for model construction which insure consistency are described in Volume 2.

Life-stanza models

Most of the preliminary biological modeling work that has been completed during Phase II has focused on the life-stanza models. There are two reasons for this emphasis. First, it is within the life-stanza models that causal links between mitigation measures and biological responses must be specified at a relatively fine level of resolution. Second, there is a perceived need to examine particular components which have not received the attention that they deserve.

Construction of life-stanza models requires a broad range of information. Table 1 summarizes the information necessary to specify each model and the inputs and outputs that might be expected. In Volume 2, each life-stanza model is discussed in more detail and example models are presented which demonstrate useful modeling techniques, often of a probabilistic nature, and the possible utility of developing such models for the real system. Some of the finding concerning each life stanza are summarized below.

Table 1 Outline of Major Features of Proposed Life-Stanza Models.

I. Juvenile Production Model

- A. Necessary information
  - fecundity relationships
  - hatchery production characteristics
  - natural production characteristics
  - outplanting alternatives
  - survival parameters
  - growth equations
  - smoltification schedules
- B. Inputs
  - number, sex ratio, age structure, and condition of adults returning to spawning areas
- C. Outputs
  - number, size, physiological condition, and timing of outmigrating juveniles

II. Downstream Migration Model

- A. Necessary information
  - natural mortality rates
  - river flow / migration rate relationships
  - dam passage relationships
  - transport policies and mortality
- B. Inputs
  - river flow, hydrosystem operations
  - number, size, physiological condition, and timing of juveniles beginning outmigration
- C. Outputs
  - numbers, size, physiological condition, and timing of outmigrants passing each project

III. Estuary and Early Ocean Model

- A. Necessary Information
  - migration parameters
  - growth parameters
  - mortality parameters

Table 1 Continued.

III. B. Inputs
- environmental conditions
- numbers, size, physiological condition, and timing of of smolts reaching the estuary

C. Outputs
- numbers and size distribution of fish recruited to ocean fishery

IV. Late Ocean Model

A. Necessary information
- natural mortality rates
- harvest rates
- maturity schedules

B. Inputs
- numbers and size distribution of fish recruited to ocean fishery

C. Outputs
- ocean harvest
- number, sex ratio, age structure, and timing of adults returning to river

V. Upriver Migration Model

A. Necessary information
- natural mortality rates
- harvest rates
- dam mortality rates
- fallback probabilities
- delay time distributions
- energetic cost and reproductive condition information

B. Inputs
- river flow, hydrosystem operations
- number, sex ratio, age structure, and timing of adults returning to river

C. Outputs
- inriver harvest
- number, sex ratio, age structure, and condition of adults returning to spawning areas

---

Juvenile Production

A central feature of the Fish and Wildlife Program is the effort to bolster production of juvenile salmon and steelhead in the Columbia River Basin, as measured by both the quantity and quality of outmigrants (smolts). The current effort to rebuild production levels includes a combination of both natural and artificial production methods, including using hatcheries to produce fry which are then released (outplanted) in natural streams for rearing. The question which accompanies each proposed measure is what impact will this measure have on juvenile production? Will it be effective? Proposed measures must be examined relative to available alternatives. Each alternative is judged based upon expectations suggested by some type of model, where in this case model refers to an assumed set of quantitative relationships.

Juvenile production is a complex, multidimensional phenomenon that is not easy to understand, much less predict. The two more popular approaches to modeling juvenile production, habitat-based models and stock-recruitment models, lack the qualities necessary for either model to be applied exclusively throughout the Columbia Basin. Production models are needed which have components of both approaches. In addition, the emphasis placed on using outplanting as a means of supplementing natural production demands that careful consideration be given to ways of representing interactions between wild and hatchery fry.

Given the mixed assortment of mitigation measures that have been proposed for tributary streams, the inconsistencies in available data, and the diverse character of the tributary basins, it seems unwise to attempt to develop a general production model that can be ubiquitously applied. A more pragmatic approach might be to focus on the tributary basins and try to develop production models that are uniquely suited for each basin. Such models will take advantage of the best available data for each basin and be tailored to fit the physical characteristics of each. Available management options within each model would be limited to those measures which are identified beforehand as being appropriate for each basin.

Modeling the Outmigration

A fairly rigid structure for accounting for losses of migrating young fish incurred in passing dams and powerhouses has been incorporated into existing models of downstream passage such as the FISHPASS model developed by the U.S. Army Corps of Engineers. Less obvious, but no less real than the losses occurring at the dams are mortality losses associated with passage through the reservoirs. The variety of approaches to modeling reservoir survival incorporated in existing models highlights the uncertainty surrounding this issue. There is an immediate need for a sound, theoretically and empirically based model of reservoir passage and survival.

A stochastic compartment model approach described in Volume 2 provides a promising method of representing reservoir passage such that the effects of current mitigation measures can be evaluated and the impact of future actions might be anticipated. A notable strength of this approach is that it allows one to distinguish changes in rate of passage from changes in instantaneous mortality rate, two components that will be affected by mitigation measures in different ways. Existing monitoring data, combined with high-quality data which are expected to result from technological advances in smolt monitoring, can support implementation of the stochastic approach described therein.

Early Marine Survival and Growth

For many Columbia Basin stocks, the relative success of each year class may be largely determined by the magnitude of the mortality incurred during their brief stay in the estuary or in their first few months in the ocean. Fishery managers face the challenge of identifying management actions that will enhance the prospects of marine survival of these stocks. While the list of available management options within the estuary and ocean is limited, managers can influence marine survival via upstream management actions which affect the timing of arrival, size, and physiological condition of smolts. Construction of applicable simulation models which might provide guidance is constrained, but not prohibited, by limited knowledge of the Columbia system.

Volume 2 describes an example model which was constructed to simulate the survival and growth of a fictitious chinook salmon stock from the time it reaches the estuary until the end of year. The purpose of this model is to refine understanding and focus debate--not numerical prediction. Based on a principal assumption that growth influences survival, results from the model indicate that timing of arrival and size at arrival substantially affect survival through the first year. The major benefit of building such models is that they identify critical data needs and point to experiments which could reduce major uncertainties, thus leading to a more effective Fish and Wildlife Program.

The Late Ocean Period

Most of the research interest in the ocean component of the salmon life cycle historically has focused on issues involving sport and commercial ocean harvest. A comprehensive discussion of ocean fishery issues can be found in Part III of Volume 2. But allocation of harvest is not the only issue of importance in the ocean fisheries. Ecological issues such as growth rates, size structure, and age at sexual maturity interact with harvest rates to influence the relative productivity and fitness of a stock and are best explored within a simulation model. The simulation model presented in Part I is a companion model which allows one to address questions outside the scope of the approach described in Part III.

The purpose of the example presented is to explore the relative importance of selected mechanisms which affect the age and size structure of maturing adults and the potential implications for stock reproductive potential. The model results suggest that under the conditions specified, stocks which mature on the basis of size as well as age have a higher reproductive potential and exhibit less sensitivity to cumulative mortality processes, such as harvest, which decrease the mean age at maturity. Ways of distinguishing such stocks and the usefulness of this information to fishery managers also are discussed.

Modeling Upstream Migration

Hydroelectric development of the Columbia Basin poses major obstacles for adult salmon trying to return to natal spawning areas. The dams which clog the mainstem Columbia and Snake Rivers effectively block or impair the upstream migration of adult fish. Poor design or inefficient operation of installed passage facilities can result in delay or mortality of migrating fish. Delay and fallback associated with dams add to the energetic cost of migration thereby reducing the energy available for reproduction and decreasing the reproductive potential of a stock.

In order to assess the chances of an individual fish making a successful spawning migration, one must be able to estimate the likelihood of available energy reserves being sufficient to cover the energetic demands of migration. Thus arise the three basic parts of a comprehensive model of upstream migration: (1) an estimate of the variability in both time expended and distance traveled in migration, (2) an estimate of the caloric demand associated with each migration path, and (3) integration of (1) and (2) to provide an estimate of the energy reserves available for spawning within a stock and the distribution of those reserves among individuals.

Volume 2 provides an illustrative example of modeling upstream migration where energetic cost is represented in a simple manner. Using the model provided, it is shown that fallback, fatigue, and fish behavioral response to delay may play significant roles in determining the extent of cumulative hydrosystem impacts on upstream migrants.

Models and Monitoring

A primary objective of a monitoring system is to maximize the information gleaned from a fixed amount of effort. A first step in developing a monitoring system is the decision of which measurable components or system attributes should be monitored. Three questions must be considered: (1) which state variables are likely to change in response to management actions, (2) can these changes be measured, and (3) how do these changes relate to overall program success. Models can assist in this process by identifying key variables that are indicative of system behavior. Models can also be used to examine questions of sampling error and provide insights as to how a monitoring scheme might be structured to reduce uncertainty in parameter estimates.

During Phase II, we have taken a preliminary look at the problem of monitoring downstream passage. A report on the problems of monitoring the outmigration which discusses the techniques currently being used and the prospects of new technologies is included in Part I of Volume 2. A critical problem in monitoring the smolt migration is that of sampling efficiency at the dams, i.e., knowing what percentage of the smolts passing a dam are actually detected by sampling devices. The probability of survival estimates produced using summary statistics turn out to be quite sensitive to errors in estimating sampling efficiency and there seems to be no easy way to resolve this problem. Consideration of the entire time series of passage data, rather than relying solely on summary statistics or indices of central tendencies, may provide more reliable estimates of survival, travel time, and sampling efficiency. A combination of new sampling technologies (e.g., PIT tags, hydroacoustics) and advanced statistical techniques holds real promise in being able to address some of the problems that have plagued smolt monitoring for many years. Realistic simulation models could provide guidance in the design of efficient monitoring schemes.

Relevance to the Power Planning Council's Modeling Effort

A legitimate concern, expressed by some in the Pacific Northwest, is the compatibility of RFF's biological modeling effort with that directed by the Council. From its inception, the effort expended at RFF has been designed to be complementary, rather than duplicative, of the modeling work completed under the direction of the Council. Our tactic has been to concentrate on areas where earlier efforts are perceived as being weak or lacking (e.g., reservoir mortality, estuary and early ocean survival and growth), to place less emphasis on areas which have received considerable prior attention (e.g., downstream passage mortality at dams, juvenile production), and to build on the modeling efforts of the Council and others.

The differences between the models which are proposed in this report and the current System Planning Model (SPM) being used by the Council result principally from the circumstances under which each approach was developed, and the intended use of the models. The model from which the SPM was developed was designed in a two-part, five-day workshop on adaptive management and the Columbia River Basin. This workshop served to introduce participants to the concept of adaptive management, and for many as an introduction to modeling as well. The SPM has proven to be a useful tool for organizing information and in providing a systematic way of hypothesizing the relative role of factors affecting fish production within and among subbasins, depending on the location of the subbasins. Given the expanded role envisioned for this model in ongoing subbasin and system planning, it is important to look critically at the capabilities of the SPM relative to the expectations being raised for its use. A brief review of the current SPM and some of the limitations of its use is presented in Part I.

Most of the material presented in Volume 2 concerns concepts in modeling the fisheries of the Columbia that are not explicitly addressed in the SPM or any other existing model. The central distinguishing feature of a hierarchical approach is the expanded scope and improved resolution offered by a suite of models versus a single model. Specifically, the proposed approach differs substantially from (and supplements) earlier approaches in the following ways:

- The relatively fine temporal and spatial resolution of the life-stanza models should allow a closer inspection of potential management impacts than do most existing models (the FISHPASS model being a notable exception).

- By integrating information from lower-level analyses, the system-level hierarchical model should facilitate basin-wide analyses that are not currently possible.

- The proposed models include explicit representation of intrastock heterogeneity, a key ecological property.

- Increased reliance on nonlinear and probabilistic relationships within the proposed approach provides a rich exposition of management-fishery relationships.

- Models are to be developed such that calculation of costs are made possible.

The narrowest differences may be between the current SPM and the proposed life-cycle models. Since both are designed to simulate the life cycle of individual stocks, the SPM might be viewed as an excellent prototype life-cycle model. One might expect to modify the internal workings of the SPM to make it more compatible with the overall design, but many of the desirable features of the SPM would be maintained.

Conclusions

We believe a basis has been established for proceeding with the application of the proposed modeling approach to the Columbia River Basin in Phase III. This is necessary not only to lead to an improved understanding of the biological processes involved in mitigation, but also it is an essential foundation for proceeding with the cost-effectiveness analyses proposed in Part II of Volume 2.

PART II - MODELS FOR COST EFFECTIVENESS ANALYSIS

Background

As indicated in the discussion of Part I, major emphasis in the Phase II work was placed upon research aimed at a better understanding and modeling of the biological aspects of the anadromous fishery. This was done since all efforts at modeling of anadromous fish mitigation must be based upon this basic ecological knowledge. But another major task of Phase II is to develop methods for assessing the cost-effectiveness of alternative mitigation measures and for identifying system-wide, least-cost management strategies for meeting biological objectives.

Therefore, it is necessary to build a simulation model that explicitly includes the ecological system, the hydrosystem (with its various hydro projects, diversions, and operating procedures), and mitigation measures, including the costs of measures (both direct costs, such as fish bypass facilities, and opportunity costs, such as foregone power to provide fish flows).

Part II deals with modeling these aspects of the system; first, with an economic-ecologic simulation model to account for both the biological and nonbiological aspects of the system, then with more advanced, and much more difficult, modeling techniques that incorporate formal mathematical search procedures designed to identify systems-wide, least-cost management strategies. The latter methods are of intense interest in a problem of this nature because, given that there are a large number of possible mitigation measures in the system, the possible combinations soon become astronomical and the possibility of selecting a least-cost set by human reasoning or intuition is remote.* This does not mean, however, that the

---

* Consider a small simulation model in which there are 28 variables (an actual water resource model may easily have many hundreds), each of which may be set at any one of three levels. There are then 3^{28} possible designs for the system. This is approximately 23 trillion. If it takes 2 minutes of computer time to simulate each design, it would require 100 million years to complete the simulation. Of course, no one would attempt a complete enumeration of outcomes in a large problem, but this calculation does suggest the complexities one faces.

economic-ecologic simulation model by itself would not be useful. Indeed, we regard it as being the basic tool to be developed in the Phase III research and the least-cost approach to be much more in the way of an important experiment. Why this is so will be explained later.

Simulation of water resource systems has become rather common place in water resource planning and management over the past generation. Indeed, several such models exist for the Columbia River Basin. Some of them are reviewed in Part II. In general, they are designed for specialized purposes rather than for comprehensive fish mitigation planning. For example, the Systems Analysis Model (SAM) is directed specifically to power planning and FISHPASS is intended to simulate downstream migration of smolts. In contrast, the proposed economic-ecologic simulation model incorporates all major aspects of the system affecting anadromous fish production. It explicitly incorporates ecological models that simulate the nature of that subsystem (the set of models discussed in Part I), and proceeds in time steps suitable for long-range planning of mitigation strategies. Therefore, implementation of the proposed economic-ecologic simulation model in Phase III would not duplicate any other research in the Pacific Northwest, but it would incorporate information from existing models to the extent feasible.

We turn next to an overview of the economic-ecologic simulation model based on Part II of the Phase II report. It is important to keep in mind that the following description is of a proposed methodology, not of an existing model or models of the real Columbia River system or any part of it. Application of the methodology is the task of Phase III.

Overview of the Economic-Ecologic Simulation Model

This model is comprised of four principal parts--a master control module, an hydrosystem simulation model, a fish production simulation model, and a cost evaluation model. The relationship among these four parts is shown schematically in Figure 4.

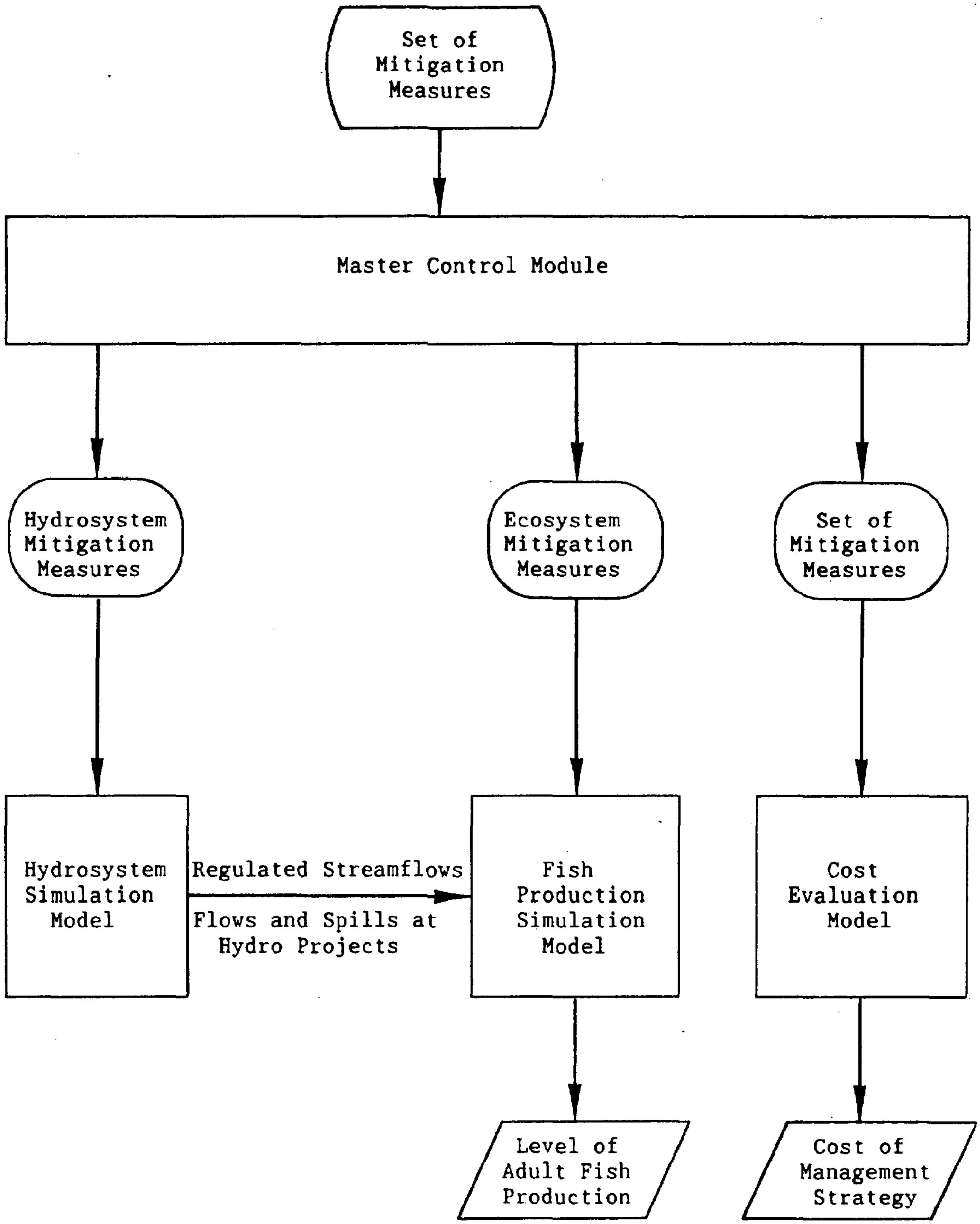


Figure 4. Schematic Diagram of Economic-Ecologic Simulation Model for Cost-Effectiveness Analyses

The master control module controls and coordinates the other three components of the economic-ecologic simulation model. Given a particular set of mitigation measures to be simulated, this module determines and assigns values for the management variables (variables that are related directly to management options such as sizes of hatcheries) and it assigns initial levels for the state variables (variables that describe the system such as streamflows and the number of adult spawners of a particular stock) in the hydrosystem simulation model and fish production simulation model. This module also organizes and reports the principal outputs of the simulation analysis--the levels of adult fish production and the costs of producing those levels.

The hydrosystem simulation model mimics the unregulated flows in the tributaries to the Columbia and Snake rivers, the operations of the storage projects in the U.S. and Canadian portions of the basin, the operations of the run-of-the river projects including the flows and spills at those projects and the generation of electricity, withdrawals of irrigation water, and the regulated flows in the Columbia River system to the estuary below Bonneville Dam. The fish production simulation model simulates the production of eggs, the rearing of fry, the migration of smolts to the estuary below Bonneville Dam, the ocean and in-river fisheries, and the migration of adult fish up the Columbia and Snake rivers and their tributaries to hatcheries and natural spawning areas.

The cost evaluation model estimates both the direct resource costs of management strategies and the opportunity costs of those strategies. It provides a time stream of future costs and it discounts future costs to present values to enable comparisons of alternative management strategies.

Hydrosystem Simulation Model

Hydrosystem simulation models are used widely in water resources planning and management. There are two basic types. One type is called a mass-balance model. For this type, the time step of the simulation cannot be shorter than the time it takes for a release of water from an upstream reservoir to be noticed at the mouth of the river. A typical time step for the mass-balance type simulation model is one month. Thus, since streamflows in this type of simulation are typically analyzed and reported as monthly streamflows, the management variables and all the other state variables in the simulation have to conform to this time scale. This type of hydrosystem simulation model is used most often for the design and operation of storage reservoirs.

The other type of hydrosystem simulation model is called a hydraulic routing model. For this type, the time step of the simulation can be as short as it needs to be to describe the particular phenomenon. A typical time step for flood routing is one hour to several hours.

A mass-balance type hydrosystem simulation model is proposed for the next phase of the research. This decision is based on two principal considerations. First, the economic-ecologic simulation model is designed to assist in long-term strategic planning and evaluation. It is not designed to support short-term management or operational decisions. A monthly time step for the hydrosystem simulation should be sufficient to assess long term impacts on the anadromous fishery. Second, a mass-balance hydrosystem model is considerably easier to build, but nevertheless consumptive of much effort, and certainly less expensive, than a hydraulic routing hydrosystem model.

The time-step in the hydrosystem simulation model is then one month. Average monthly conditions are used to describe the essential features of the hydrosystem, such as levels of the storage reservoirs, streamflows, water withdrawals for irrigation, and the production of hydroelectric power, and average monthly conditions are used to estimate costs and to assess impacts on anadromous fish.

The principal inputs to the hydrosystem simulation model are the unregulated monthly streamflows, the initial reservoir levels at the storage projects and pool levels at the run-of-the-river dams, and the levels of the hydrosystem management variables such as monthly irrigation water withdrawals and the proportion of total monthly flows at each dam that pass through the turbines, through the fish by-pass, and over the spillway. These inputs are provided by the master control module for each system-wide mitigation strategy analyzed.

The principal outputs of the hydrosystem simulation model are the monthly regulated streamflows in the basin, the average time of passage of water through the reservoirs by month of year, and the monthly flows at each hydro project that pass through the turbines and the monthly spills at these projects that pass through the fish by-pass conduits and over the spillways. These outputs are passed along to the fish production simulation model.

Fish Production Simulation Model

Fish production simulation models are not as well developed as water resources (hydrosystem) simulation models. This is due partly to the more complicated biological relationships involved in fish production and migration, partly to the lack of data, and partly to the more recent use of quantitative mathematical models and computers in the analysis of ecological systems. An approach to simulation modeling of the production of anadromous fish in the Columbia River system has been described in connection with Part I. This set of models with necessary adaptations will be used in the economic-ecologic simulation model.

There are two groups of inputs to the fish production simulation model from other parts of the economic-ecological model. One group of inputs is provided by the master control module. The other group is provided by the hydrosystem simulation model. The principal inputs from the master control module are the levels of the management variables that pertain to the ocean and in-river fisheries such as the number of fry or smolts that are released from hatcheries, the capacities of natural spawning and natural rearing habitats, and the distribution of the ocean harvest, the in-river harvest, and the adult fish that are permitted to spawn. The principal inputs from the hydrosystem simulation model include the monthly regulated streamflows throughout the basin, the average time of passage of water through the reservoirs by month of year, and the monthly flows at each hydro project that pass through the turbines, through the fish by-pass conduits, and over the spillway.

The principal outputs of the fish production simulation model are the levels of adult fish production measured by the number of adult fish that are harvested in the ocean, the number that are harvested in the river, and the number that are permitted to spawn, for each year in the planning period and for each stock considered in the analysis.

Cost Evaluation Model

The cost evaluation model estimates both the direct resource costs and the opportunity costs of all fish mitigation measures considered in the analysis, organizes these costs by the year that they are incurred, and computes the present value of the time stream of costs for each mitigation strategy.

Economic Criterion and Costs

Some further words about the economic criterion to be used may be useful. The economic criterion specified for model development and analysis by BPA in the agreement between BPA and RFF is "cost-effectiveness". This has been defined operationally for purposes of model design and development to include three kinds of analyses: (1) assessment and comparison of the costs of a set of prespecified fish mitigation strategies that achieve the same level of effectiveness (level of adult fish production), (2) an assessment and comparison of the costs and levels of adult fish production of a prespecified set of fish mitigation strategies that achieve different levels of effectiveness, and (3) identification of the most cost-effective system-wide (or subsystem-wide) management strategy for achieving a particular biological objective, subject to a set of administrative, legal, and political considerations imposed on the analysis.

Economic costs are defined as changes in total social costs due to implementation of a particular management strategy. In practice, costs are measured as changes in the sum of the direct and indirect costs due to the primary effects of a set of protection, mitigation, or enhancement measures. Thus, costs are measured relative to conditions that are projected to exist in the basin throughout the 20 year planning period, with and without the fishery management strategy in place.

The costs included in the analysis are those that are incurred in the U.S. and Canadian portions of the basin. For some analyses, the opportunity costs of reductions in the ocean harvest may also be included (see the discussion of Part III below). Changes in the operations of the storage projects in the Canadian portion of the basin are assumed to be part of the cost-effectiveness analysis, although the operations of these projects could be fixed at current levels if this alternative is not a viable one. (The Columbia River Treaty with Canada is subject to renegotiation in 1995.) In comparing the costs of alternative management strategies, costs that occur at different times in the analysis will be presented both as a stream over time and as discounted present values.

As indicated earlier, two types of economic costs are considered in this analysis. The first type is the direct resource costs of the fish mitigation measures, such as the capital, operating and maintenance, and land costs of fish hatcheries, collection and transportation equipment used to transport smolts around dams, and adult fish ladders.

The second type of economic cost is the indirect resource costs of fish mitigation alternatives, referred to as "opportunity costs", associated with changes in the operation of the hydrosystem for the benefit of anadromous fish. Examples include the economic losses associated with withdrawing water from hydroelectric production and possibly, by means of purchase of water rights, from irrigated agriculture to improve reservoir and dam passage. Part II contains an extensive discussion of both conceptual and empirical issues with respect to estimating these two types of opportunity costs. Part III, to be discussed shortly, presents a comprehensive analytical approach to estimating the opportunity costs of increased, or more effective, regulation of ocean fisheries.

We turn now to the problem of identifying the system-wide or subsystem wide least-cost management strategy.

Approaches to the Least-Cost Analysis

As indicated, there are basically two approaches to attempting to identify the set of least-cost mitigation measures for a specified biological objective. The first approach is the scenario, or simulation, approach. In this approach, a set of management options called a scenario is specified completely. There are no choice variables in the analysis. The analysis involves simulating the effects of the scenario and assessing the outputs of interest--the total system-wide cost of the set of mitigation measures, the number of fish reaching maturity in the ocean, and the number of adults of a particular stock escaping the ocean fishery and returning to the Columbia River to be harvested or to spawn. A number of scenarios are developed and analyzed, and the outputs of interest are compared. The scenarios are ranked according to the economic criterion adopted for the analysis, in this case the minimum total cost of meeting a target level of adult fish of a particular stock or set of stocks. In this approach, identification of the set of least-cost measures is not guaranteed. In fact, as also already indicated, because of the abundance of possible alternative measures, identification of the least-cost set would be highly unlikely.

The scenario approach is relatively straightforward from a computational perspective. For the most part, as already explained, this approach involves integrating various simulation models (e.g., cost, hydrosystem, and fish production simulation models) and applying standard principles of engineering economy.

Because the simulation approach is unlikely to identify the set of least-cost mitigation measures, a second approach , mathematical programming (e.g., linear programming, mixed-integer linear programming, and nonlinear programming), invites consideration. In this approach, the particular trial alternatives to be assessed are not specified a priori. Rather, the programming model is used to make a formal organized search for that combination of potentially available fish hatcheries, levels of enhancement of natural spawning and natural rearing habitats, operations of hydro projects, streamflows, and other mitigation measures that can satisfy the least-cost criterion, subject to limits such as those on power requirements and water availability, legal requirements, etc. (called constraints). In principle, if the model is properly structured, this assures that a least-cost solution will be found from among those pre-specified measures available to the model.

In addition to differences in the computational complexity of the mathematical programming and simulation modeling approaches, there may also be differences in the accuracy of their outputs. Because mathematical programming models tend to grow large in size (measured by the number of management and state variables and by the number of constraining relationships) and thus to become difficult to manage and in some cases "unsolvable", simplifying assumptions are often required. These simplifying assumptions can affect the accuracy of the results obtained from these models.

Assumptions made to reduce the size of mathematical programming models are generally not required of simulation models. Thus, simulation models are able to provide more accurate assessments of the costs and ecologic implications of particular mitigation measures than programming models. Therein lies the dilemma. Simulation models are able to provide more accurate assessments of the costs and the fish production implications of particular mitigation measures, but they are weak in their ability to identify the set of least-cost measures. Mathematical programming models are designed to identify the least-cost set of measures, but due to the simplifying assumptions that are generally required, they do not mimic reality with the fidelity of simulation models. Although each approach has desirable features, neither is entirely satisfactory for the needs of the Columbia River Basin fish mitigation analysis. This suggests a combination of the two approaches.

Perhaps the best way to view mathematical programming for large, complex economic-ecologic systems such as fish production in the Columbia River Basin is as a "screening" device to assist in identifying a candidate set of technically feasible management strategies with desirable cost-effectiveness properties. This set of strategies can then be simulated using the more detailed economic-ecologic simulation model. The latter will provide more accurate estimates of the mitigation costs and more accurate estimates of the fish production implications of the various mitigation strategies, but may also show that the candidates identified in the screening do not withstand more accurate analysis. In that case, an iterative procedure between the two approaches may have to be developed.

These considerations led us to search for a suitable analytical framework for least-cost analyses. For large scale applications such as this, the most desirable model structure from a computational perspective is a linear programming (LP) model. This is an elegant mathematical structure for solving least-cost problems and is very efficient for finding optimal (e.g., least-cost) solutions. In order to be able to use linear programming, though, all the cost functions and all the constraining relationships must either be linear or be approximated by linear segments. That means that none of the variables in the model can be multiplicative with other variables. An important example of a non-linear relationship in the present context involves electric power production from a variable head hydro project. Power is the product (in the mathematical sense) of the hydraulic head and the flow through the turbines. Thus, a model involving variable head hydropower production cannot be a linear model.

In the typical least-cost problem, it is not always possible to approximate all the nonlinear relationships with linear segments. The power-head relationship is such an instance. Therefore, it is not always possible to use linear programming. However, it is sometimes possible to use a technique that introduces integer variables to eliminate the remaining nonlinear relationships. This requires the use of mixed integer linear programming, the next most desirable model structure for large scale applications; one, however, that is mathematically much more complicated and computationally much more demanding than linear programming. In this case, then, the number of integer variables becomes a practical consideration along with size (characterized by the total number of variables and the total number of constraining relationships) in real applications. If mixed integer linear programming cannot be used, it may be necessary to use nonlinear programming. This is the least desirable model structure for large scale applications. Nonlinear programming models typically consume large amounts of computer time and they do not guarantee identifying the "global" (as opposed to "local") least-cost strategy.

The approach used to identify the structure of the least-cost model in this Phase II research was, first, to establish priorities for the structure of the model and, second, given these priorities, to investigate what was possible. The following priorities were established for the structure of the model: linear programming model, mixed integer linear programming model, and nonlinear programming model, in that order. Thus, the approach taken assumed a linear programming structure and proceeded to determine if that structure could accommodate the physical and biological processes associated with fish life-cycles and with the management of water resources in the Columbia River Basin. This required developing all the relationships in the model to determine if they were linear. For those relationships that were not linear, it required specifying the assumptions that were necessary to linearize the (nonlinear) relationships or to eliminate the nonlinear relationships altogether. In those cases where it was not possible to linearize a particular nonlinear relationship, consideration was given next to the use of integer variables to eliminate that nonlinear relationship. This process convinced us that mixed integer programming for the problem at hand might be feasible and that further development of it was warranted.

The mixed integer linear programming model is described by "module". A module is defined as a set of activities performing similar functions. There are seven modules in all. The first three modules pertain to the hydrosystem. They are called "storage", "hydropower", and "irrigation", respectively. The last four modules concern the fish life-cycle. They are called "smolt production", "smolt migration", "ocean harvest and survival", and "upstream migration of adults," respectively. The last four modules depend to a large extent on the outputs of the first three.

In addition to being divided functionally into modules, the least-cost model is also divided temporally into time periods. The overall time horizon for the model is fifteen years, for the following reasons. It is known that many stocks, especially the wild upstream stocks, are severely depleted in comparison to their historical levels forty to fifty years ago. Because of the many obstacles they face, including habitat limitations for spawning and rearing, downstream passage of smolts, ocean harvest, and upstream passage of potential spawners, it seems probable that it will take several generations for runs of these stocks to return to acceptable levels. Therefore, in principle at least, it is necessary to model the life-cycle of stocks for two, three, or more generations, of two to five years each (from spawning to returning adult spawners), in order to identify the mitigation measures and the levels of those measures that will be needed over the coming years to return stocks to acceptable levels. As discussed in Part II, this poses a considerable challenge for existing mathematical programming algorithms and computers.

The planning period in the model is divided into one year segments. Each year is further divided into twelve months. This level of disaggregation is needed in order to reflect temporal variability in the hydrologic cycle, in the demands for electricity and for irrigation water, in storage requirements at the storage projects, and in salmonid life-cycles and migration. While it might be desirable from a computational perspective to collapse the model into fewer years and fewer "months" per year, reducing the temporal resolution would invariably reduce the accuracy of the results.

The model that emerged from this effort is unique and reflects a truly major effort in Phase II to come to grips with the feasibility of developing a least-cost programming model. Our investigations so far lead us to believe that "decomposition" procedures present a promising approach to the otherwise probably intractable problem of model size. We believe that an experimental application of the mixed integer model to an actual subbasin should be attempted in the next phase of the research. We say more about this in the last section of this summary report where we address the matter of approaches to Phase III.

As already indicated, Part II contains an extended discussion of conceptual and empirical problems involved in estimating the opportunity costs of certain fish mitigation measures. The focus is on foregone hydropower and changes in the consumptive use of water in irrigation. Part III, to which we now turn, does the same for regulation of the ocean fishery.

PART III: OCEAN FISHERIES MANAGEMENT

Background

As mentioned in the introduction to this summary volume, one of the more important factors in reducing upstream runs has been the development of a large ocean fishery that intercepts adult fish before they can return to the river. For reasons that will be expanded upon later, this fishery is also very economically inefficient. These factors suggest that improved regulation of the ocean fishery could be an important mitigation option with respect to the upstream runs and the productivity of the fishery in general. To compare this alternative with the cost of other options, as explained in Part II, it is necessary to compute the opportunity cost or net value foregone when ocean fishing is restricted or other regulatory measures are put in place. Before getting into the question of appropriate methods and data for analysis of this issue, however, a bit of fishing history will provide useful background.

While native Americans had fished the Columbia River since "time immemorial" as the treaties say, their fishing appears to have been fairly well in balance with the productive capacity of the river. Early nineteenth century settlers of European origin began to fish the river, but around 1865 a more important development affecting and continuing to affect the fisheries occurred.

At that time, salmon canning was introduced and almost overnight Columbia River salmon products were sold in worldwide trade. These were products ranging from luxury high priced items to low cost food for factory workers in England. At this point, in response to the apparent market potential, new fishing technologies were introduced. This involved gillnets, seines, fishwheels, and fishtraps. As a result, catches of salmon increased substantially.

Estimates are that by 1900, there were 2,800 gillnetters operating on the river. The Columbia River Fishermen's Protective Association was formed to advance the interest of the gillnetters. The membership of this union was restricted; the meetings were lengthy and closed to non-members.

Membership requirements for this association included the exclusion of liquor dealers, capitalists, lawyers, and politicians. Union strikes were frequent and snag vessels were used to eliminate the equipment of nonparticipants and of fishermen other than gillnetters. The gillnetters made many efforts to pass legislation to eliminate other forms of fishing. To this point, however, they had not been successful.

In 1902, the stage was set for further changes. Voters in Oregon passed a constitutional amendment to provide for statewide initiatives and referendums. As a result,the people of the State of Oregon could actually both make and veto laws. Through this process, the gillnetters, with backing from the Grange, the Oregon Federation of Labor, and the Oregon Fish Commission, placed laws on the books designed to eliminate fish-wheels, fish-traps and forms of fishing other than gillnets. This was done even though fish-wheels and fish-traps are efficient methods of taking salmon.

The important point here is that the gillnetters were able to win this battle for the fish in the Columbia River primarily because, in numbers, they were the largest group. This, unfortunately, is just the opposite of what might have been most desirable from the standpoint of efficient use of a common property or open access resource. That is, a large number of fishermen, using a relatively inefficient harvesting technique were now the primary harvesters of the Columbia River salmon resource.

As more and more restrictive legislation and regulations were passed governing the use of the salmon stocks on the river, an important technology development occurred which caused ocean fishing to become technically feasible. The gasoline engine was developed to the point where it could be adapted for fishing vessels. This started a substantial move out beyond the mouth of the Columbia River into the ocean for salmon fishing. A primary purpose was to escape from the restrictive regulations regarding gear and other activities on the River. The off-shore fishing technique (trolling) is also inefficient when compared to possible river methods such as fish-wheels or traps.

Therefore, the Columbia River salmon commercial operations in the river (gillnetters) and off-shore (trolling) evolved to the present day situation. Since the early 1900s to the present time, the Columbia River based fisheries have been affected by expanding fishing effort and the imposition of a multitude of complex fishing regulations. This situation along with various other factors (e.g., logging, dams, pollution, and fishing by foreign fleets) were the impetus for the development of a number of attempts to improve the salmon management scheme.

An important chapter in the history of salmon management began in 1976 with the passage of The Fishery Management and Conservation Act. This Act was passed for the purpose of attempting to rationalize domestic fishing effort and (probably primarily) to control foreign fishing within two hundred miles of the U.S. coasts. Regional Fisheries Management Councils were established to carry out the requirements of the Act. Included among the eight councils was the Pacific Regional Fishery Management Council which has the responsibility for managing, among other species, the salmon stocks that are exploited off the coasts of Oregon, Washington, and California. There has been considerable controversy regarding the Councils and their effectiveness. Certainly, the management of salmon under the Council is complex and difficult. One reason is that the Council has no genuine authority within the three-mile territorial sea. These areas are under the authority of the state management agencies. Therefore, considerable coordination, cooperation and compromising has been necessary in order to develop the Fishery Management Plans that now control the harvesting of salmon stock off the coasts of three states.

The management of Columbia River salmon is also complicated because of the ocean migratory pattern of the stocks. The Chinook, for example, migrate as far north as southern Alaska. This means that the Columbia River Chinook and Coho are intermixing with other salmon populations and species up and down the coast. The harvest in a particular area, therefore, will generally include individual fish from a number of different populations. Interaction among these populations in a given fishing area represents a complication in the management process. That is, if one stock is relatively weak (small in numbers) while another stock is strong, normal fishing on the strong stock may tend to over-fish or even eliminate the weak stock. The same is true, of course, with respect to wild and hatchery stocks. When many hatchery fish are stocked in the river, they intermix with less abundant wild fish. The allowable harvest on the hatchery stocks can result in serious over-fishing and further declines in the wild stocks. In practical terms, what this means is that heavy fishing off the coasts of British Columbia and Southern Alaska has impacted on the Columbia River stocks, especially Chinook. It has been difficult for fishery managers to attain an effective agreement to reduce fishing on the Columbia River stocks in the northern areas because reducing the allowable harvests of Columbia Chinook stocks meant a substantial reduction in the harvest of Alaskan and Canadian stocks. This was especially complex because the agreement of both the Canadian fishery management agency and the agencies involved in the Alaskan fisheries was essential. Each would not agree, however, without assurances that if fishermen in their area were restricted, fishermen in the other areas would likewise be restricted. This is important because half or more of the fish originating in the Columbia River are caught off the coasts of Canada and Alaska.

However, in the mid 1980s a treaty was signed between Canada and the United States that may make effective regulation of the Pacific salmon fisheries possible. The previous lack of an enforceable agreement relative to the Canadian and Alaskan catch of Columbia River stock made any rational mitigation or enhancement plan impossible. Now, however, with the treaty, and the possibility of establishing appropriate harvest restrictions off the coasts of Canada, Alaska, California, Oregon, and Washington, it should be possible to develop regulations that will enhance upstream runs as salmon stocks are increased. This possibility makes improved understanding of the economics of the ocean fishery especially important.

How to Model the Ocean Fishery

The approach adopted to pursue a better understanding of the economics of the ocean fishery is to first specify a model of the fishery. Various specific costs and benefits from alternative ocean fishery management approaches, and economic impact studies, are then keyed to the model. The issues as to the type of model that would be most appropriate, simulation versus optimization (mathematical programming) are generally similar to those discussed in connection with Part II. In this regard, mathematical programming offers a potentially attractive way to model the bioeconomics of the ocean fishery for salmon, and provides a means to explore the effect of different management alternatives on these relationships. Some of the advantages of a mathematical programming approach include: (1) it has the potential capability of handling large variable sets and provides a means of exploring the tradeoffs between ocean and in-river harvest and examining the economic impacts of changing ocean harvest practices; (2) it provides the opportunity to incorporate a detailed model of the ocean fishery integrally into the programming model discussed in connection with Part II or to link it more loosely, via adults produced and returning fish, to the ecological-economic simulation model; and (3) it does not preclude the late ocean life stanza simulation model discussed above in connection with Part I. Indeed the two complement each other since exercising the latter can be the basis for providing improved inputs for the former. Unfortunately, mathematical programming offers only limited opportunities to consider stochastic elements of the fishery problem.

Policies developed to change recruitment or escapement are likely to require a detailed representation of the types of salmon present in the ocean fishery. Such policies are likely to focus on enhancement of wild stocks and on increased releases of hatchery stocks. Thus, the spawning source needs to be distinguished in a salmon fishery model. Management programs also will be concerned about population differences among rivers. Hence, spawning location and species composition become important. The age and size of salmon also are important: policies that increase fishing in the lower Columbia River will, for example, increase the catch of older larger salmon relative to policies which encourage off-shore fishing. Given such policy options, salmon would need to be distinguished by spawning source, spawning location, species, and age or size.

Faced with so many attributes, homogeneous variable definitions can be obtained only by defining large variable sets. Suppose, for example, salmon subpopulations are defined for six ages, two species, two spawning periods, five spawning locations, and twelve successive runs or cohorts. 1,440 variables would then be required to completely describe the salmon fishery's population. Mathematical programming models have the potential to consistently evaluate such large sets of variables.

As explained in connection with Part II, when a large number of variables is defined, simulation and mathematical programming gain prominence in the list of possible modelling approaches. Simulation offers a positive ad hoc approach which can include stochastic elements. Identification of good or better solutions is, however, often a matter of judgement. Mathematical programming is a normative deterministic approach in which an explicit objective function is specified, and solutions are unambiguously ranked according to a particular criterion. The explicit objective function provides the necessary foundation for the computation and interpretation of "shadow prices" for the uncaught salmon. These values are a key benefit of the mathematical programming alternative because they indicate the marginal value of relaxing a constraint, for instance, the value of permitting an extra day of fishing.

Although shadow prices are one of the most valuable results from a programming model, they are only one of several potential outputs. A mathematical programming model of the ocean salmon fishery would determine whether a set of escapement goals could be attained when recruitment and catch are at particular levels. It would provide a profile of an optimum harvest, and could show how this harvest would be affected by various controls on fishing effort or intensity. The model could also be used to isolate the effect of changes in recruitment levels on the number and type of salmon caught, the value of the fishery, and the number of salmon escaping to the river. We believe this set of potential results is rich enough to justify consideration of a mathematical programming formulation of the ocean fishery in Phase III.

In furtherance of this goal, a detailed mathematical formulation of a programming approach is presented in Part III. It includes consideration of both linear and non-linear programming models. The linear approach would fit neatly into the total system modeling approach discussed in Part II, if it were desirable to include it, while adoption of a non-linear ocean fishery model would present complications that would have to be examined in Phase III.

Implementations of either modeling approach would need to assign economic values, with respect to ocean fisheries, to changes in salmon stocks. Determining these is in itself a major research undertaking and we turn next to a brief consideration of approaches to these problems.

Valuing Changes in Salmon Stocks

Assessment of the economic benefits from actions which change salmon stocks should account for the gains and losses to individuals in their roles of consumers, producers and resource suppliers. The central objective of estimating such benefits, to repeat, is to obtain opportunity cost values for regulation of the ocean fishery comparable to the opportunity cost of foregone power and reduced irrigation, and to the direct cost of other mitigation alternatives for increasing the upstream runs. We do not intend to estimate benefits of the river fishery in this project since quantitative biological goals are to be set for stocks and geographical areas of emphasis by the Regional Council.

The notion of economic benefits includes the concepts of producers' surplus and rents to resource suppliers, that is the returns over and above the costs of doing business. Consumer surplus is analogous, representing the difference between the maximum amount of money an individual would be willing to pay and that which he must pay in the market to enjoy the use and consumption of a commodity.

These two concepts can be applied equally well to the commercial and recreational salmon fishing sectors. The benefits from increasing salmon available to the commercial sector (or the losses from reduced salmon stocks) will include the change in surpluses to fishermen, processors, retailers, and the ultimate consumers. Often, these can be deduced from information on aggregate demand and supply in the salmon market, information typically available as a consequence of market transactions. The specific application of the surplus concepts to the commercial sector and the problems which arise in empirical measurement are discussed in detail in Part III.

The recreational sector presents a greater conceptual and empirical challenge. The benefit measure (changes in consumer surplus or willingness-to-pay) is applicable to recreationists. However, there is no clearly defined market as in the commercial sector. The nature of the recreational experience further complicates the research. The recreationist is consuming a commodity which is more than just salmon; he is consuming a recreational fishing experience which is enhanced by increased salmon catches. When the commodity in question is not marketed, individuals' surpluses (or willingness-to-pay) cannot be calculated from market demand functions, and standard techniques for approximating this willingness-to-pay measure using market data cannot be employed.

When no markets exist for the commodity the researcher can choose between two approaches. One can identify markets for related goods, making indirect calculations of willingness-to-pay, or one can ask individuals directly what their willingness-to-pay would be. The various approaches, together with their strengths and weaknesses, are also discussed in Volume 2. While in general a preference is expressed for indirect methods because they are based on actual behavior, final determination of a methodology to be followed for benefit estimation would be made in Phase III.

Determination of Economic Impacts

While the net benefit type of analysis first discussed is appropriate to analyses aimed at economic efficiency and cost effectiveness, local and regional interests will also (or only) care about local income and employment impacts. In general, approaches measuring economic impact can be made through economic base methods, input-output models, and the adaptation of input-output models to include econometric functions.

The foundation of the regional economic impact studies involves analyses that relate output of industries in the area or region in question with inputs needed to produce the output. The use of this information permits the determination of how all outputs and inputs will be affected by a change in one output (e.g., fish). The total effect of the change after the adjustments take place can be determined for the value of output, income level and labor requirements.

Part III contains a detailed discussion of the modifications needed in standard input-output analyses to make it suitable for regional economic impact analysis in the Pacific Northwest.

Concluding Comments

A research program to implement the ocean harvest research discussed in Volume 2 would be large. The reward, however, would be the first comprehensive study of the economics of managing the Columbia River based ocean fishery. Untold dollars have been spent on partial studies of limited utility that tend to serve particular purposes but then to disappear into the pages of journals and specialized reports. What would be required for the proposed Phase III research is a joint effort of various agencies and universities in the region. Thus, even if BPA were to provide substantial funding, a major collaborative effort would be required to bring off the full effort.

COMMENTS ON THE PHASE II DRAFT REPORT

The Phase II draft report was released for public comment in February 1988. The draft report consisted of four parts: a Summary Report; Volume I, Modeling the Anadromous Fisheries of the Columbia River Basin; Volume II, Economic-Ecological Modeling for Cost-effectiveness Analysis of Mitigation Alternatives; and Volume III, Ocean Fisheries Harvest Management. The draft Summary Report was mailed to over 200 individuals representing a broad spectrum of interests. Fewer copies of the technical volumes were distributed but they were made available upon request. Around 50 copies of each of the technical volumes were sent out for review. Written comments were solicited from those receiving the reports. In addition, public meetings were held in Portland, Oregon, and Seattle, Washington, on March 3 and 4 to allow those receiving the reports an opportunity to ask questions and make oral comments on the draft report. Total attendance for both meetings was approximately 50 persons (Appendix A).

A considerable number of comments were received, mostly oral. The nature of the comments reflects the regional significance of this work and the diverse opinions and interests of the various groups in the Pacific Northwest. The comments that were received may be broadly classified into three categories: (1) those which do not support further research of this type by RFF or BPA, (2) those which support further research but have technical questions about the ecological modeling approach which has been proposed, and (3) those which support the research but question the types of economic analyses which have been proposed. Our response to these concerns is expressed below. It is aimed mainly at the written comments (Appendix B); to a large extent these comments mirror the oral comments that were received.

Justification for Further Research

Two major objections were raised by those who opposed further research of the type described in the Phase II Draft Report. For some, the research is seen as being duplicative of other ongoing efforts in the region.

Others view the research as being beyond the level that is needed to provide information for regional decision making.

While these issues are addressed in various places of this report the main points are reviewed briefly here. In the ecological modeling reported in Part I of Volume 2, the orientation was to emphasize parts of the system which had little research attention in previous efforts. Also an effort was made to design more detailed models of the various life stanzas than are available otherwise. For example, modeling approaches were proposed for reservoir mortality and for estuary and early ocean growth and survival, and probabilistic modeling approaches to all elements of the life cycle were explored in detail. The level of detail of the proposed models is necessary if the biological effects of particular mitigation measures or sets of measures are to be simulated. Furthermore, existing models have little or no capability to assist in the analysis of the cost-effectiveness of particular measures or sets of measures, especially on a systemwide, full life-cycle basis. Accordingly, as explained in Part II, non-biological aspects of the system must be included in the modeling; for example, hydropower and irrigation opportunity costs, as well as costs of mitigation structures and their operation. This need is the basis for the proposed simulation and optimization approaches discussed in Part II, which in turn are built upon the biological approaches and understanding represented in Part I.

Ecological Modeling Issues

A number of those commenting on the draft report were supportive of a systematic effort to develop analytical methods for assessing the potential impacts of alternative mitigation strategies on fish production. The proposed hierarchical structure for modeling the salmon and steelhead fisheries received several favorable comments. Questions were raised concerning (1) the extent to which existing models could be incorporated within the proposed structure, (2) whether there are sufficient data to support the types of models which are proposed, (3) the appropriateness of specific assumptions that were made in building the example models, and (4) how such models would be used in making management decisions.

In response to these concerns, it must be understood that further development of the biological models will require a coordinated regional effort. The purpose of the Phase II research was to lay out a blueprint for the types of models that are needed and how they might work in concert. A comprehensive system of working models of the Columbia River system has not been developed. Regional scientists and managers have the system experience and the information available to them that is necessary to characterize the system and put in place an analytical system which includes an integrated suite of biological models. RFF can help provide the technical expertise that is necessary to assemble such a system but cannot proceed alone. A substantial portion of this new system should be wrought from existing models and data bases. The inclusion of two such models, the System Planning Model developed by the Council and FISHPASS, is addressed within Part I of Volume 2. Much of the data that are needed for modeling is expected to be produced in the ongoing system and subbasin planning process. Where data are lacking, model development should help in identifying critical data needs as explained in Chapter 1 of Part I. Also, there will always be certain stocks for which data are relatively scarce. In such cases it will be necessary to carefully extrapolate inferences from analyses of better understood stocks to those for which information is lacking.

In a large, complex system such as the Columbia, there will always be differences in opinion as to how the system should be modeled. Debates over what level of resolution is appropriate, which assumptions are most likely to be correct, which mechanisms should be included in a model, et cetera, are to be expected and encouraged. The beauty of modeling is that it is relatively easy and cheap to explore alternative hypotheses using models as compared to experimenting with the real system. There is a fundamental difference between management by consensus and modeling by consensus. The purpose of management is to provide tangible benefits. The purpose of modeling is to provide information. While only a single, coordinated management strategy can be expected to maximize benefits, having a single model which is based on a solitary view of the system does not maximize information. Thus those comments which suggest alternative models of the system are welcome; future modeling efforts will consider these comments in the design and analysis of alternative models. The proper role of such models in management and research is discussed in Part I.

Understanding the Economics

The objections to the economic analyses proposed in the Phase II Draft Report concerned both the method and the scope of the analyses. Some reviewers objected to the choice of cost-effectiveness analysis, and suggested that a benefit-cost analysis might offer a more complete economic assessment of the mitigation alternatives. Others argued that the proposed analyses go too far in trying to incorporate all of the tradeoffs inherent in the mitigative measures into a cost-effectiveness framework, both because many of the tradeoffs are difficult to quantify and because the system is too large and complex to reduce to a single least-cost solution.

These objections correctly point out that no single analytical tool is a panacea. While cost-effectiveness analysis readily allows one to evaluate alternatives with non-monetary biological objectives, it sidesteps the issue of whether the benefits of attaining a specified objective outweigh the costs. An ideal economic analysis addresses this economic efficiency concern, as well as distributional, welfare, and equity issues. On the other hand, a benefit-cost analysis, while incorporating more efficiency concerns, forces one to transform many non-monetary values into dollar terms.

In any case, the agreement between BPA and RFF specifies that cost-effectiveness and not benefit-cost analysis is the approach to be used in the economic analyses. Furthermore, the direct language of the Regional Act which mandates the mitigation efforts stipulates that decision-makers, when faced with multiple options which achieve the same level of biological effectiveness, must employ the alternative that minimizes the economic cost of achieving the specified biological objective.

Because many of the biological goals involved in mitigation will reach across the entire system (for example, adult anadromous fish production requires analysis of the entire range of the fish life cycle from spawning grounds to the ocean), the Act also specifies that a systemwide approach be taken. This means that the cost-effectiveness analysis should incorporate as many of the economic tradeoffs as possible, across the entire system. A piece-by-piece, project-by-project economic analysis may not yield meaningful results if the inter-relationships of the pieces are ignored and the system is not analyzed as a whole.

This does not mean that the analysis will attempt to determine a single least-cost solution, however. Rather, the approach will be to use cost-effectiveness to explore the various options and to eliminate clearly inferior solutions. The proposed mathematical programming model can incorporate a variety of non-economic goals, such as the maintenance of upstream populations, as constraints which limit the range of alternatives and assess the costs and tradeoffs of achieving these non-economic goals. As the goals change, the model would yield different results. The simulation model would be able to evaluate this set of results more completely.

It is important to note that cost-effectiveness analysis should not serve as a decision rule. It is merely one of several tools to aid in the evaluation of various options. Decision-makers still need to specify both the objectives to incorporate in the analysis and the alternatives to pursue.

APPENDIX A

Register of those attending the public discussions held in Portland and Seattle concerning the draft Phase II report.

Portland, Oregon; March 3, 1988

Name	Affiliation
Tom Pansky	Bonneville Power Administration (BPA)
Mark Danley	BPA - Public Involvement
Larry Larson	BPA
Greg Drais	BPA
Janet McLennan	BPA
John Palensky	BPA
Stan Detering	BPA
Jerri Krier	BPA
Jonathan Mills	BPA
Doug Arndt	U.S. Army Corps of Engineers (COE)
Jim Athearn	COE
Art Gerlach	COE
Ed Woodruff	COE
Bolyvong Tanovan	COE
Richard Kruger	Fisheries Consultant
Darryll Olson	Argonne National Laboratory
Willa Nehlsen	Northwest Power Planning Council (NPPC)
Peter Paquet	NPPC
Chip McConnaha	NPPC
John Marsh	NPPC
Rick Applegate	NPPC
Ron Eggers	NPPC
Barbara Taylor	NPPC
John Volkman	NPPC
Kathryn Kostow	Pacific Northwest Utilities Conference Committee
Jack Donaldson	Columbia Basin Fish & Wildlife Authority
Earl Webber	Columbia River Intertribal Fish Commisson (CRITFC)
Phil Roger	CRITFC
John Platt	CRITFC
Jim Seger	Pacific Fisheries Management Council
Brian Kinnear	U.S. Fish and Wildlife Service (USFWS)
Dick Edwards	USFWS
Emery Castle	Oregon State University

Seattle, Washington; March 4, 1988

Name	Affiliation
Robert Francis	Fisheries Research Institute, U.W. (FRI)
Jim Anderson	FRI
Charles Simenstad	FRI
Steve Mathews	FRI
Gordon Swartzman	Center for Quanitative Science, U.W. (CQS)
David Ford	CQS
Christine Ribic	CQS
David Fluharty	Inst. for Marine Studies, U.W.
Dick Nason	Chelan County PUD
Mike Erho	Douglas County PUD
Bob Clubb	Puget Sound Power and Light Company
Labh Sachdev	Seattle City Light
Cindy Monk	Seattle City Light
Roy Metzgar	Snohomish County PUD
Stanley Detering	BPA
Kathryn Kostow	PNUCC
Chip McConnaha	NPPC
Dennis Rohr	Mid Columbia PUDs
Wesley Ebel	National Marine Fisheries Service

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION, CORPS OF ENGINEERS
P.O. BOX 2870
PORTLAND, OREGON 97208-2870

REPLY TO
ATTENTION OF:

March 31, 1988

Planning Division

Allen V. Kneese
Senior Fellow
Resources For The Future
1616 P Street
Washington, D.C. 20036

Dear Mr. Kneese,

Enclosed are comments from my staff on the three volumes of the draft report, Design of Studies for the Development of BPA Fish and Wildlife Mitigation Accounting Policy. These comments are primarily technical in nature. We understand, as per discussions with Stan Detering of BPA, that BPA will be seeking additional input from the regional agencies and interested parties on the appropriateness of BPA funding further model development.

Your studies recommend several models that will fully trace the life cycle of salmon and steelhead. Many of these models currently exist in some form and you have suggested improvements to them. This sort of consolidation and improvement to existing (and often competing) models is critical to an objective examination of the numerous fish mitigation proposals. The next logical step would be to prioritize the next stage of study. Since many interested parties should help in this prioritizing step, we suggest you consider a workshop to receive regional input.

We found the meeting held on March 3 to be very informative and many of our initial questions were addressed in a follow up meeting between Danny Lee, Doug Arndt, Ed Woodruff, and Bolyvong Tanovan. Thank you for this opportunity to comment on this excellent effort by Resources for the Future.

Sincerely,

DA Geiger
for D. E. Olson
Chief, Planning Division

3 Enclosures

Copy Furnished:
Stan Detering, BPA

SUBJECT: NPD COMMENTS ON - - VOLUME 1: MODELING THE ANADROMOUS FISHERIES OF THE COLUMBIA RIVER BASIN

1. Modeling Downstream Migration. The report, and particularly in chapter 4, recognizes that the modeling of passage at the main-stem dams with the Corps of Engineers' FISHPASS model is appropriate, but, better accounting of reservoir mortality is needed. Unfortunately, the report does not fully recognize the importance of fish transportation (see first paragraph, page 4-5) in eliminating concerns with reservoir mortality. We agree there is a need for detailed reservoir passage modeling. The Corps, however, feel that reservoir mortality could be substantially reduced by increasing transportation from dams that now have that capability.

2. The probabilistic approach proposed for juvenile migration through reservoirs is original and intriguing. Models developed to date, with some exceptions, have been mostly deterministic in nature, using concepts that are intuitive and logical. The lack of pertinent information, due primarily to enormous physical and practical constraints, has prevented the models from generating extremely accurate results. It is not certain that the RFF new approach will not be faced with the same problem of lack of needed data. Even assuming that sufficient data will be collected, the need to relate fish migration to flows and migration timing still remains, so that the model can be used for practical applications. How this would be accomplished with the RFF proposal is not clear. It should be noted that the current "routing" method used in the Corps' FISHPASS model already leads to a bell-shaped curve for fish arrivals at downstream pools.

3. Estuary Model. This model represents a new tool which may provide substantial management insight. We suggest that the estuary and early ocean model include separate accounting of the transported and non-transported fish to examine if their is a difference in mortality.

4. Chapter 7, Modeling Upstream Migration of Adult Salmonids.

a. Harvesting of upstream migrating adults is not included in the conceptualized model (see page 7-5.) Indian harvest is a major restriction to adults and as runs increase there will be added pressure for increases in gill netting and sport catch. Without accounting for harvest we do not see how this model could be useful.

b. We strongly question the concept of each fish having a limited "fuel tank" and that spawning efficiencies are significantly impacted by the amount of "fuel" used in the upstream migration. The studies that we are aware of (see bibliography below) do not support this basic concept. We do not see extensive biological modeling of the upstream migration as a high priority and think that a simple accounting model may suffice. That is, simply account for the number of salmon that are caught and show where each species exit the main Columbia to tributaries to spawn.

c. Bibliography of Pertinent Studies.

Lisrom, K.L. and Stuehrenberg, L.C. Radiotracking Studies of "Upriver Bright" Fall Chinook Salmon Between Bonneville and McNary Dams, 1982. Sept 1983. Final Report to BPA (DE-A179-82BP36379).

Stuehrenberg, L.C. and K.L. Lisrom. A Study of Apparent Losses of Chinook Salmon and Steelhead Based on Count Discrepancies Between Dams on the Columbia and Snake Rivers, 1967-1968. Aug 1978. Final Report to the Corps of Engineers (Contract # DACW 57-67-C-0120).

Ross, C.V. Evaluation of Adult Fish Passage of Bonneville Dam 1982. July 1982. Final Report to the Corps of Engineers.

Shew, D.M. et al. Evaluation of Adult Fish Passage at McNary and John Day Dams, 1985. 1906. Final Report to the Corps of Engineers.

5. Page A-4. The discussion provided here gives the impression that fish hauling is not an implementable activity in the long run. We strongly disagree with this statement and have numerous study findings to support our opinion. It must be recognized that currently fish hauling represents the major form of mitigation in the critical low water years.

SUBJECT: VOLUME 2: ECONOMIC-ECOLOGICAL MODELING FOR COST-EFFECTIVENESS ANALYSIS OF ALTERNATIVES

1. The cost effectiveness criterion does not answer the basic question of whether a biological goal is "worth" the cost. That is, no comparison of benefits to costs of a biological goal is accomplished with the cost effectiveness analysis. Many of the fish improvement proposals require trade-offs with hydropower. The power act requires "equitable treatment" of fish and hydropower and since all power plan elements are tested from an benefit-cost approach, it follows that fish programs also should be economically tested to the extent possible.

SUBJECT: VOLUME 3: OCEAN FISHERIES MANAGEMENT

1. The examination of the critical economic concerns with the salmon and steelhead ocean fishery is very thorough and well done. Many of the proposed model elements have been of concern to region economists for years, but, the lack of budget priorities have restricted any one group from funding the necessary research.

2. The determination of economic values of commercial and recreational fishery should not be limited to the ocean fishery. As stocks increase throughout the PNW in the next several years, in-river fisheries will again become a major economic concern. Furthermore, the economic value of steelhead is limited to the in-river fishery. By ignoring this component of the fishery RFF will miss its goal to provide a comprehensive model to examine all fish mitigation and enhancement proposals.

United States Department of the Interior

BUREAU OF RECLAMATION
PACIFIC NORTHWEST REGION
FEDERAL BUILDING & U.S. COURTHOUSE
BOX 043-550 WEST FORT STREET
BOISE, IDAHO 83724-0043

IN REPLY REFER TO: PN 734/150

APR 1 - 1988

Allen V. Kneese
Resources for the Future
1616 P Street NW.
Washington, D.C. 20036

Dear Mr. Kneese:

We received your draft report "Design of Studies for Development of BPA Fish and Wildlife Mitigation Accounting Policy, Phase II Report" dated January 1988.

The Bureau of Reclamation has been supportive of the fish and wildlife mitigation program under the Northwest Power Act since its inception in 1980. We have participated in wildlife mitigation team meetings with State, Federal, and tribal representatives on each of our hydroelectric projects in Montana, Washington, and Idaho. We have worked to achieve wildlife mitigation plans on these projects and are looking forward to their implementation. We are also still involved with fish and wildlife issues that are being addressed in the various committees on a project and subbasin basis.

After reviewing your draft report, we offer some comments of a general nature.

We question the need for yet another computer model of the Columbia Basin anadromous fisheries. There only needs to be one model for the basin, and the development and use of the model should be a cooperative effort of the involved agencies and tribes who should work together to establish the location of the model, level of detail needed, structure, research needs, etc. Perhaps a Columbia Basin anadromous fisheries model technical work group could be established to reach agreement on the parameters of a fisheries model that all would accept as technically accurate and adequate.

There would also seem little need to develop another hydrosystem model. Existing models should be able to provide the necessary information/ simulations.

It is not clear how the fish production and migration model discussed on page 35 differs from the model discussed in volume 1.

Overall, it would appear that much of the computer modeling and other aspects discussed in the report are already underway by various entities concerned with Columbia Basin anadromous fisheries. Rather than starting another, new effort, perhaps BPA should consider a role of facilitator in bringing ongoing efforts together under one "umbrella." In this way, efforts could be coordinated, directed, and expanded in a manner that would meet all needs at a minimum cost to taxpayers and ratepayers.

Thank you for the opportunity to review this report.

Sincerely yours,

John W. Keys, III

Regional Director

SIMON FRASER UNIVERSITY

NATURAL RESOURCES
MANAGEMENT PROGRAM
FACULTY OF APPLIED SCIENCES

BURNABY, BRITISH COLUMBIA
CANADA V5A 1S6
Telephone: (604) 291-4659

3 April 1988

Dr. Allen V. Kneese
Resources for the Future
1616 P Street N.W.
Washington, D.C. 20036

Re: Draft Summary Report of BPA Project

Dear Dr. Kneese,

Thank you for sending me the "Draft Summary Report: Design of Studies for Development of BPA Fish and Wildlife Mitigation Accounting Policy" dated January 1988. Unfortunately, I was unable to read this until now and was therefore unable to provide you with detailed comments before your deadline of 1 April. However, I wanted to do a thorough job and I hope that these comments will still be useful. I have sent a very similar letter to Danny Lee.

General Comments

The Draft Summary Report is extremely well written and RFF's work to date on this project is admirable, both in its scope and in the care with which the various techniques are being explored. In particular, I think that the sections relating to Volume I on the potential uses of simulation modelling are excellent. The authors note that a compromise must be found between models that are too detailed to understand and ones that are too simple to have much utility. They further emphasize the role of modeling in design of future research projects, sensitivity analysis of management alternatives, etc. Even though I do a lot of modeling, all of these statements are philosophically in line with the "healthy skepticism" that I think one should take towards the use of models. However, I do have three major comments on the simulation modelling work done to date, as well as that proposed.

First, the Volume I models appear to be too detailed. It seems very unlikely that you will be able to get, on all relevant stocks, the requisite detailed parameter values related to size-specific mortality rates, for example, or other detailed components. This type of detailed modeling seems at odds with the careful compromise on detail that was discussed on page 12 of the Summary Report. The problems with the detailed International Biological Program models in the 1970s illustrate that too much detail can reduce the chances of meeting the stated objective of the modeling exercise.

Contd. p. 2....

Second, Volumes II and III that deal with economic analysis and management of ocean fisheries appear to be headed toward formal optimization. Other than your observation that such methods can help to "screen management alternatives," I have difficulty envisaging how the simulation work will interface in a meaningful way with the proposed optimization work. It is easy to say that the simulation will produce outputs that will be inputs to the optimizations, but without any clear examples of this, I foresee difficulties. I have seen too many cases where different groups of people have taken different quantitative approaches and have not had their models interact. This problem will have to be worked on very carefully, with perhaps workshops that serve to ensure that outputs from one model provide information on variables that is at the spatial and temporal scale required by the next model up in the hierarchy. A systematic process for doing this is our "looking outward" approach, which is outlined in Chapter 4 of Holling et al. (1978).

Third, I could find no mention of the potential interactions that could occur among stocks of the same species, or with other species. Yet such interactions have been found to be important in many situations. In the enclosed review paper (Peterman 1987), I tried to document that there are density-dependent processes in the marine environment that can lead to rehabilitation projects generating fewer economic benefits than anticipated. For example, density-dependent growth exists within stocks (pink and sockeye salmon) and among stocks from widely separated streams that intermingle on the high seas (sockeye). Density-dependent marine survival has been documented for one sockeye salmon population in B.C., and while Nickelson's (1986) paper purported to show that this density-dependent process did not exist in coho salmon from the Oregon Production Index area, his sample sizes (years) are so small that the power of his results is too low to draw a firm conclusion. In other words, the probability of detecting density-dependent marine survival, even if it truly exists, is so low with his data, that his failure to detect significant density-dependence should not be taken as firm evidence that such a process does not exist. It was a weak test. I am writing a paper on this topic soon, and as I will outline below, I think that the concept of statistical power is extremely important not only to the modeling of the Columbia River system but also to the large-scale experimental design. There are numerous other examples of interaction among stocks and species, such as through predation by coho smolts on pink salmon. These are documented in the "grey literature" of internal management agency documents.

Specific Comments

I have further comments on the indicated pages of the Summary Report.

Contd. p. 3....

Page 5 --I agree that a system-wide approach to the planning and implementation is essential. This is what I stressed to Kai Lee from the start; without coordination in a careful experimental design, extensive confounding of effects of various actions could occur, making it impossible to ascertain which mitigation efforts were working and which were not.

--The stated goal of doubling the number of adults is identical to the Canadian Salmonid Enhancement Program's (SEP) goal in 1977, and my concern about SEP's goal applies equally to the Columbia River case. If the goal of doubling production is based upon historical catches, one cannot conclude that it will necessarily be possible to get back to that level of production for two reasons: 1) oceanographic processes, which are known to affect survival and growth on the high seas, are not constant and long-term trends exist that may make the ocean less productive (or more so) than in the past. Thus, past production may be only a very rough guide to what the ocean can support in the future. 2) Ricker (1973) shows that there is an element of "fishing up" even in salmon fisheries. This means that peak historical yields may not be obtainable again.

-- I also wonder if it might be more appropriate to state the goal in terms of the desired increase in <u>total biomass</u> of adults, rather than simply numbers of fish. Certainly, this is more important to the commercial fishermen, who earn income on the basis of weight caught. Sports fishermen may indeed only want the number of fish to increase, regardless of their size (as long as it is within a reasonable range). This issue should be discussed before you formulate the objective functions for the optimization models. This comment arises from the density-dependent growth dynamics that I alluded to above. Weight of individual sockeye adults can be as much as 22% below their largest size when they are present in the Gulf of Alaska with large numbers of conspecifics (Peterman 1984). Density-dependent growth is therefore a significant effect that can influence the economic benefits from a mitigation effort (Guthrie and Peterman 1988). This is one mechanism by which you may start to receive decreasing marginal benefits from further mitigation efforts.

--At the bottom of page 5, you indicate that some mitigation and enhancement measures can be pursued without formal analysis. Fine, but what about an experimental design to formally test whether they are working? We have had too many surprises in management of ecological systems to continue assuming that new management regulations will always have the desired effect.

Contd. p. 4....

Page 7 --Task One. The large system-wide model that is planned may go well beyond the ability of data to provide reliable parameter estimates. A very similar dilemma was encountered by Barnthouse et al. (1984) who were involved with modeling of mitigation efforts by power plants to maintain fish populations. I strongly recommend that your staff have a look at the lessons from that work, if they are not already familiar with it. Barnthouse et al. found that a simpler model was the only credible one in the end, and the original goals of the project had to be changed.

Page 8 -- Tasks Two. Given the lack of an experimental design from the outset of dam construction on the Columbia, I doubt whether you will be able to attribute the reduction in fish stocks to hydroelectric projects, let alone to other causes, man-made or natural. The only thing that comes to mind is that the different starting dates of the dams may permit the fitting of a "staircase design," (Walters, Collie and Webb 1988) which might be able to assign confidence intervals to the relative proportions of losses attributable to different causes. Jeremy Collie, now one of my Research Associates here at Simon Fraser University, was a coauthor of that work and he is currently fitting this 'staircase design" to similar types of data on fish stocks that have been disturbed by a temporal sequence of management actions.

--Task Three. Again, changes in total biomass production of adults should be one measure of progress. The staircase model might also be applicable here.

Page 13 -- The hierarchical approach to modeling the system is good. Perhaps the final product should include a "hierarchical information package" (Gross et al. 1973). The objective of this package would be to increase the number of users or readers who understand the assumptions of the various levels of models. The more that the assumptions are understood, the more wisely the models will be used by the managers. This technique was used by Gross and his colleagues to help bridge the gap between scientists and managers, a goal that most modelers don't take seriously. The Gross et al. document is probably not obtainable any more and it is several hundred pages long, but it was a report submitted to RFF (it must have been part of an RFF contract). Alternatively, Jack Gross is with the US Fish and Wildlife Service in Fort Collins, Colo.

Page 20 --Again, without examining the possibility of density-dependent growth or survival processes after the smolting stage, your models are likely to overestimate the benefits that will arise from any enhancement method. At the very least, you need to ask, "How strong would such density-dependent processes have to be before we change our management recommendations?"

Contd. p. 5.....

Page 22, bottom --While managers of enhancement facilities can indeed try out different tactics to influence marine survival, if left to their own devices, proper evaluation of those tactics may not be possible. Each treated group of fish (e.g. small size at release) should be marked and have a control group (normal size). There should be replicates of treated and control groups so that the effect of the treatment can be tested statistically. However, if each hatchery manager independently performs these manipulations as he sees fit each year, the composition of smolts (in terms of size, timing of release, and physiological state) from the Columbia system as a whole will differ from year to year. This will confound any attempts to statistically test hypotheses having to do with density-dependent marine growth and survival because the "abundance of smolts" variable will not be the same each year. Thus, careful consideration should be given to the tradeoff between local-level and large-scale experimentation.

Potential Future Contributions

In your letter, you asked for additional comments on how readers might be able to contribute to Phase III on this project. Through Kai Lee, I am aware of some of the work that the staff of the Council are doing, but I am not exactly clear how RFF's responsibilities differ from those of the Council. So some suggestions below may be more appropriate to the Council.

Since 1977, I have been working on the components of recruitment of Pacific salmon, concentrating on the relatively neglected marine life stage. I have empirically tested numerous hypotheses related to processes that affect year-to-year variation in marine survival, growth, and age at maturity (reviewed in Peterman 1987). I could contribute some of those findings and methodologies for testing to the Columbia River coho and chinook situation. (I have enclosed several papers in Danny Lee's copy of this letter). I have also done extensive simulation modeling of fish population dynamics, including the chinook and coho salmon in Georgia Strait of British Columbia (Argue et al. 1983). I therefore might be able to assist with some of the simulation modeling in Phase III.

In 1982, I gave a 2-day short course on large-scale experimental design to Oregon Department of Fish and Wildlife staff (Jim Lichatowich in Corvallis organized it). Given that one major theme of the BPA project is a system-wide examination of mitigation solutions and monitoring to determine their success, experimental design should play a significant role. Scientific staff may understand the principles of experimental design, but those managers who will implement the "operational plan" for various projects may not. The latter in particular may not realize the potential confounding effect of different actions at different locations along the migration route. Perhaps I could again run a workshop on experimental design.

Contd. p. 6....

While this 1982 workshop helped to convince managers in the Oregon region that a large-scale experimental approach was necessary, the experiment that they proposed later that year had low statistical power. They suggested that, instead of continuing to increase the abundances of smolts released each year, smolts should be held constant at 48 million per year in order "to test once and for all if there really is density-dependent marine survival." Unfortunately, this experiment had a low probability of detecting density-dependence, even if it existed (Peterman and Routledge 1983). Thus, the experiment had low statistical power. Subsequent work by myself and other people has documented that statistical power is an extremely valuable concept that can be applied to problems such as the rehabilitation of the salmon stocks of the Columbia River. In that situation, it is possible to calculate the probability that one will be able to observe an effect of some mitigation measure, if an effect really exists. If the set of individual experiments being carried out simultaneously results in a low probability of seeing an effect, then the experimental design should be improved. In contrast, a high statistical power will confirm that the experimental design is reasonable, at least from one viewpoint.

I have been doing research on this area of statistical power recently (e.g. Peterman and Routledge 1983; Peterman and Bradford 1987) and I believe that not only should managers be aware of its significance, but so should researchers. I could contribute research on the application of this statistical power concept to the BPA project to ensure sound experimental design. As well, part of a short-course on experimental design could include a section on statistical power.

Conclusion

Your staff and that of the Northwest Power Planning Council are doing an excellent job on this project. This will become a precedent-setting stock rehabilitation program and at this stage it looks like it will also have valuable methodological spinoffs. I appreciate being asked for comments and I would like to be put on the mailing list for future reports. I hope that my comments are useful.

Sincerely,

Randall M. Peterman

Randall M. Peterman
Professor

References

Argue, A.W., R. Hilborn, R.M. Peterman, M.J. Staley, and C.J. Walters. 1983. Strait of Georgia chinook and coho fishery. Can. Bull. Fish. Aquat. Sci. 211:1-91.

Barnthouse, L.W., et al. 1984. Population biology in the courtroom: The Hudson River controversy. BioScience 34:14-19.

Gross, J.E., J. E. Roelle, G.L. Williams. 1973. Program Onepop and information processor: A systems modeling and communications project. Progress Report, 327 pp, Jan. 1973.

Guthrie, I.C. and R. M. Peterman. 1988. Economic evaluation of lake enrichment strategies for British Columbia sockeye salmon. N. Amer. J. Fish. Manage. (In press).

Holling, C.S. (ed.). 1978. Adaptive Environmental Assessment and Management. John Wiley & Sons, Chichester, England, 377 pp.

Nickleson, T. 1986. Influences of upwelling, ocean temperature, and smolt abundance on marine survival of coho salmon in the Oregon production area. Can. J. Fish. Aquat. Sci. 43:527-535.

Peterman, R.M. 1984. Density-dependent growth in early ocean life of sockeye salmon. Can. J. Fish. Aquat. Sci. 41:1825-1829.

Peterman, R.M. 1987. Review of the components of recruitment of Pacific salmon. Amer. Fish. Soc. Sympos. 1:417-429.

Peterman, R. M. and M.J. Bradford. 1987. Statistical power of trends in fish abundance. Can. J. Fish. Aquat. Sci. 44:1879-1889.

Peterman, R.M. and R. D. Routledge. 1983. Experimental management of Oregon coho salmon: designing for yield of information. Can. J. Fish. Aquat. Sci. 40:1212-1223.

Ricker, W.E. 1973. Two mechanisms that make in impossible to maintain peak period yields from stocks of Pacific salmon and other fishes. J. Fish. Res. Board Can. 30:1275-1286.

Walters, C.J., J. S. Collie and T. Webb. 1988. Experimental designs for estimating transient responses to management disturbances. Can. J. Fish. Aquat. Sci. 45:539-547.

ARGONNE NATIONAL LABORATORY
6915 S.W. Macadam Avenue, Portland, Oregon 97219

April 4, 1988

Drs. Allen Kneese, Danny Lee,✓
and Walter Spofford
Resources for the Future
1616 P St. N.W.
Washington, D.C. 20036

Gentlemen:

Thank you for the opportunity to comment on your Phase II study report for the Bonneville Power Administration. It is my view that the work you have outlined for Phase III of the study is consistent with the "minimum economic cost" stipulation of the Northwest Power Act, under the provisions for fish and wildlife mitigation, and this work is necessary in order for the Bonneville Power Administration to demonstrate that the agency is exercising prudent decision making in funding select mitigation options.

The following comments support the broad objectives of RFF's Phase III study methodology but offer some suggestions regarding changes in focus and pose relevant study questions inherent to both policy and technical considerations.

Economic Analysis and the Fish and Wildlife Program

The work outlined for Phase III represents one of the few efforts to couple formally economic analysis with the planning framework of the Fish and Wildlife Program. The use of economic analysis in implementing the Program has not been emphasized, because the Act mandated that hydroelectric power operators were responsible to mitigate damages inflicted on the Columbia River fisheries. The Act made clear that Congress had decided the fisheries should be protected to the extent practical. Still federal and nonfederal project operators must absorb program costs and carry through implementation, while at the same time adhering to the basic tenants of prudent utility practice. As a result, the need to demonstrate fiscal responsibility is a dominant concern for the power community.

Reflecting the goals of diverse constituencies, Congressional intent surrounding the application of economic analysis to the tradeoffs for fishery mitigation can be an imprecise and contradictory guide, as presented in the legislative history of the Act. Congress expects regional power planners to give fish and wildlife interests "equitable treatment" with power production objectives, while ensuring Pacific Northwest residents of an "economical" power supply, and that the fish and wildlife mitigation provisions should not subvert the power objectives of the Act. The direct language of the Act provides that cost-effectiveness analysis can be employed to designate a preferred option when two different measures can achieve the same mitigation function. Even so, there is nothing in the Act to suggest that this sole provision restricts, or should be construed to restrict, conventional methods of resource economics or regional planning.

The Act does not stipulate to economists and regional planners what analysis methods can or cannot be used, any more than it dictates to ecologists the methodological parameters of environmental science. If decision makers and society do not understand or are not made aware that the costs of fishery mitigation are "real"--which economic analyses can demonstrate--then there is little reason to expect a "societal appreciation" for future costs to the resource caused by present-day management decisions. This latter point regarding the need to preserve the value of today's investments for fishery benefits relative to the future is strongly emphasized by the Council staff as a justification for their "protected areas" concept.

It is likely that the drafters of the Northwest Power Act intended resource planners to employ a full range of analytical methods to assess mitigation options. And it is evident that resource management decisions should be based on institutional/equity considerations, as well as the guidance afforded by the insights of the physical and social sciences. **Within this context, economic analysis provides one form of evaluation--an evaluation tool as opposed to a decision rule--it is not the sole criteria for decision making, nor should it be banished from the decision-making arena.**

The Policy Environment

As you discovered (but already knew) during the Portland workshop, your study proposal is viewed with great skepticism by the region's fishery agency and tribal resource managers, in addition to some Northwest Power Planning Council staff. Much of this skepticism has little to do with technical concerns, but much to do with the regional politics of fisheries management and electric power planning. Under the Act, the agency and tribal fishery managers have gained considerable leverage over mitigation planning and implementation, as they pursue their mission to restore the Columbia River Basin fish runs. For the agency and tribal resource managers, restoring the runs takes precedence over other concerns--a priority nurtured to some extent by the general public support for restoration and by political forces from within the region and elsewhere. An added factor is that recent improvements in the size of the fish runs have reinforced the "spirit of success" held among the resource managers.

The resource managers perceive any action that might stiffle the restoration effort or shift control of the planning/implementation process away from their pervasive influence as a threat to their mission. The RFF study is definitely viewed by the resource managers as a threat. Also, the RFF study engenders two other stigmas: the fact that you are "outlanders" from Washington, D.C. (everyone from the Pacific Northwest possesses a regional-centric outlook); and that you propose to infuse economic analysis into the restoration planning effort--a concept that many ecologists and resource managers view as roughly akin to "unmitigated evil." It is generally believed by the resource managers and fishery advocates that resource economics studies seldom favor the resource under investigation.

A wellspring for further apprehension, the RFF ecological and economic modeling work would lead, in all likelihood, to greater specificity or detail for the available planning options, that might highlight the deficiency of some proposed (or existing) mitigation actions. Greater certainty does not necessarily favor the resource managers position within the planning process. As the situation now stands, uncertainty works in favor of the resource managers--the results from an unsatisfactory mitigation action can be justified as part of the "adaptive planning" process advocated by the Council. ANL's experience with the Rock Island project reflects, to a significant degree, the preference for doubt in some circumstances. Considerable resistance to ecological modeling and economic analysis was voiced by the resource managers. They asserted that attempts to develop ecological models would lead to gross inaccuracy or provide too broad a range of values to be meaningful; and that economic analysis of the settlement agreement was not necessary, inappropriate under the Fish and Wildlife Program, or merely a venture in metaphysics. Several times, the resource managers (and agency attorneys) indicated that our analyses should be "qualitative" in nature.

Consequently, regardless of your independent and objective status in relation to the issues, your proposed work will be opposed. It will be very difficult for BPA officials to bear the brunt of the political opposition to your proposed study. It will be easier for BPA officials to hold the present course, allowing the Council and the resource managers to designate the direction of the mitigation and compensation efforts, with BPA placing some ceiling on the overall magnitude of the expenditures.

The Scope of the Proposed Project

The scope of the proposed Phase III study is far reaching, though project size is largely determined by the complex questions you seek to answer. Nevertheless, this bold undertaking easily falls prey to criticisms that "any modeling effort that large will never work," or that "the study is too theoretical." To combat these criticisms and demonstrate the utility of your study results, you may want to modify your work to limit its initial physical scope and to concentrate on some of the more fundamental problems underlying the application of economic analysis to fishery mitigation issues.

As you have indicated informally, the study should first concentrate on one of the subbasins within the Columbia River system, in order to refine the methodology and display its utility for resource planners. There is a considerable temptation to recommend the Yakima Basin for this trial application, but existing planning decisions may preclude this basin from offering anything other than an academic afterthought for your endeavors. You may want to consider the Salmon/Snake river basins instead, where fishery mitigation actions can be considered along with the effects of hydroelectric project operations, potential new hydro development, and the economic consequences, if any, resulting from other competing water uses (agriculture). Interestingly, you may find your study approach shifting to a methodological framework reminiscent of the comprehensive river basin planning proposals developed during the 1950's and 1960's.

Focusing on Pragmatic Issues

To my knowledge, a set of standard application procedures for implementing the cost-effectiveness criterion, as it applies to fishery mitigation, does not exist. This is a real "nuts and bolts" type of problem;

it may appear to be pedestrian in concept from the perspective of resource economists and regional planners, but actual application factors are seldom straightforward. ANL's experience in applying economic analysis to fishery impacts and mitigation measures in the Hamma Hamma, Snohomish, and Salmon river basins and to the Rock Island Project suggests that there are always intricate problems to solve at the technical level. Or approaching the broader conceptual picture, can one compare the cost-effectiveness of mitigation actions only at the same project site, or can/should one set of project mitigation actions be compared to another set of actions, where similar "biological objectives" can be met? What will be the guiding standards?

Staff from the Bonneville Power Administration, the Council, and the PNUCC have been introduced to the concept of "principles and guidelines" for applying economic analysis to the Fish and Wildlife Program. Perhaps RFF is the proper group to direct the preparation of such guidelines. **And perhaps development of the guidelines should be a priority of the Phase III study.**

Another question closely linked to the issue of cost-effectiveness and principles and guidelines is that of **systematic mitigation monitoring.** There likely will be a need to prepare an "account system" to determine whether mitigation actions are performing satisfactorily (to the extent such determinations can be made). This monitoring system presumably will provide data for estimating the cost-effectiveness of similar actions under consideration or serve as a verification component. Account system development may be a reasonable objective for RFF to pursue during the Phase III work as well.

Fishery Benefits

Although some question exists about continuing the Volume III work, it is in the public interest to review and expand upon the existing knowledge of fishery benefits estimation. Moreover, there is a need to address fishery benefits derived within the Basin, as well as from the ocean commercial catch. The reason that Idaho resource managers are interested in restoring fish runs in the Salmon River Basin is not to produce benefits for the ocean commercial fishery but to increase fishery benefits in Idaho. This same situation holds true for the perspective of the Yakima Indian Nation. But the costs of "delivering" fish to Idaho or central Washington are far greater than simply providing fish for the ocean commercial catch. So being, why limit an evaluation of marginal fishery benefits to only the ocean fishery? It is disconcerning that the benefits gained from the mitigation efforts made upriver are not included in the RFF study. Similarly, it can be asked: what direct benefits, if any, will be transferred from the agricultural community (water allocation implications) to the fishery interests to develop new, upriver spawning grounds? Also, if we are willing to measure secondary benefits (use of I/O models) derived from the commercial fishery and acquired by costal industries and communities, what prevents us from measuring the secondary economic impacts from steelhead fishing (recreation industry) in Idaho County, Idaho?

Economic Benefits of the Indian Fishery

Two areas that deserve further study are the economic significance of the fishery to the Columbia River Basin Indian tribes, and how the economic benefits from the Indian fishery can be enhanced to increase the well-being of tribal members. This is, of course, outside the purview of the existing Phase III methodology, but it is an issue worthy of investigation by both RFF and the Bonneville Power Administration--particularly given the legal/political influence of the tribes to secure fishery mitigation and compensation actions.

In the Rock Island Project EIS, ANL devoted attention to a review of the economic well-being of the Basin tribes and to the economic impacts of the tribal commercial fishery. In summary, we determined that: 1) it is apparent that the tribes' economic well-being is significantly below the level of the general population; 2) the tribes do not necessarily receive a high level of economic benefits from direct income received from the natural resources industries, such as the commercial fishery; and 3) the Indian commercial fishery is a marginal income source for the tribal community-at-large, representing an estimated 5% of total tribal income in 1985. The distribution of the fishery income within the tribes was not determined, though this equity concern is an important factor that should be reviewed.

Yet because tribal economic well-being is "fragile", every income source is important. What becomes a meaningful question is how can economic planning be instituted to maximize resource benefits for the tribes? For example, are their ways to transfer income from the Basin sport fishery to the tribes through reallocation of the harvest? Or can the added value of the fishery processing and retail sectors be acquired by the tribes through implementation of an industrial development program, perhaps funded directly by tribal investment capital or through the BIA? There are, no doubt, other possibilities available to the tribes if entrepreneurial measures are meshed with the fishery resource. And unlike the present condition, the economic measures contemplated above would disperse the economic value of the fishery among tribal households that are not directly engaged in the primary fishing enterprise. This income redistribution would not affect the Indian ceremonial and subsistence fishery.

The RFF Study and Public Policy

Public policy decisions are pursued in the interests of equity and social welfare. Fisheries mitigation and enhancement actions under the Fish and Wildlife Program primarily serve an equity function, redistributing benefits (market and nonmarket) to those segments of society that have incurred costs in the past, are currently incurring costs, or likely will incur costs due to the operation of the hydroelectric system. By carefully assessing the expenditures to fulfill equity, social welfare is promoted as well. Bonneville Power Administration's review of fishery mitigation and enhancement expenditures, through the RFF study, is conducive to the agency's legal obligations to honor fiscal responsibility. The review efforts proposed by RFF merit support by the Bonneville Power Administration and the Northwest Power Planning Council.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
500 N.E. Multnomah St., Suite 1692
Portland, OR 97232

April 14, 1988

Dr. Allen Kneese
Resources for the Future
1616 P. Street N.W.
Washington, D.C. 20036

Dear Dr. Kneese:

This is in response to your request for comments on Resources for the Future's Phase II research program planning documents titled, Design of Studies for the Development of BPA Fish and Wildlife Mitigation Accounting Policy. The document represents a considerable amount of work and we appreciate the opportunity to provide comments.

In general, we are concerned that the scope of the work proposed in your Phase II research planning documents far exceeds the level necessary to develop the tools and information Bonneville needs to carry out its fiduciary responsibilities under the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Power Act). The proposed work also duplicates ongoing efforts by the Northwest Power Planning Council (Council) and the fish and wildlife agencies and tribes in developing system and subbasin models and represents significant competition for limited funds for research and other activities under the Council's Fish and Wildlife Program.

Mitigation and compensation measures under the Power Act are not required to satisfy a cost/benefit threshold. However, where there are several equally effective means of achieving the same sound biological objective, section 4(h)(6)(C) of the Power Act requires the use of the alternative with the minimum economic cost. Therefore the economic cost of alternatives must be determined in order to select the minimum cost alternative.

However, the proposed modeling described in the planning documents includes an assessment of cost-effectiveness tradeoffs rather than only directing the evaluation to the assessment of costs of equally effective alternatives. This assessment would include developing quantitative estimates of technical, legal (including treaty Indian fishing rights), institutional, political, and management constraints. We see no useful purpose in this exercise, and consider it inappropriate to attempt to translate constraints of this nature into a quantitative form.

the fishery to the Columbia River Basin Indian tribes, and how the economic benefits from the Indian fishery can be enhanced to increase the well-being of tribal members. This is, of course, outside the purview of the existing Phase III methodology, but it is an issue worthy of investigation by both RFF and the Bonneville Power Administration--particularly given the legal/political influence of the tribes to secure fishery mitigation and compensation actions.

In the Rock Island Project EIS, ANL devoted attention to a review of the economic well-being of the Basin tribes and to the economic impacts of the tribal commercial fishery. In summary, we determined that: 1) it is apparent that the tribes' economic well-being is significantly below the level of the general population; 2) the tribes do not necessarily receive a high level of economic benefits from direct income received from the natural resources industries, such as the commercial fishery; and 3) the Indian commercial fishery is a marginal income source for the tribal community-at-large, representing an estimated 5% of total tribal income in 1985. The distribution of the fishery income within the tribes was not determined, though this equity concern is an important factor that should be reviewed.

Yet because tribal economic well-being is "fragile", every income source is important. What becomes a meaningful question is how can economic planning be instituted to maximize resource benefits for the tribes? For example, are their ways to transfer income from the Basin sport fishery to the tribes through reallocation of the harvest? Or can the added value of the fishery processing and retail sectors be acquired by the tribes through implementation of an industrial development program, perhaps funded directly by tribal investment capital or through the BIA? There are, no doubt, other possibilities available to the tribes if entrepreneurial measures are meshed with the fishery resource. And unlike the present condition, the economic measures contemplated above would disperse the economic value of the fishery among tribal households that are not directly engaged in the primary fishing enterprise. This income redistribution would not affect the Indian ceremonial and subsistence fishery.

The RFF Study and Public Policy

Public policy decisions are pursued in the interests of equity and social welfare. Fisheries mitigation and enhancement actions under the Fish and Wildlife Program primarily serve an equity function, redistributing benefits (market and nonmarket) to those segments of society that have incurred costs in the past, are currently incurring costs, or likely will incur costs due to the operation of the hydroelectric system. By carefully assessing the expenditures to fulfill equity, social welfare is promoted as well. Bonneville Power Administration's review of fishery mitigation and enhancement expenditures, through the RFF study, is conducive to the agency's legal obligations to honor fiscal responsibility. The review efforts proposed by RFF merit support by the Bonneville Power Administration and the Northwest Power Planning Council.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
500 N.E. Multnomah St., Suite 1692
Portland, OR 97232

April 14, 1988

Dr. Allen Kneese
Resources for the Future
1616 P. Street N.W.
Washington, D.C. 20036

Dear Dr. Kneese:

This is in response to your request for comments on Resources for the Future's Phase II research program planning documents titled, Design of Studies for the Development of BPA Fish and Wildlife Mitigation Accounting Policy. The document represents a considerable amount of work and we appreciate the opportunity to provide comments.

In general, we are concerned that the scope of the work proposed in your Phase II research planning documents far exceeds the level necessary to develop the tools and information Bonneville needs to carry out its fiduciary responsibilities under the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Power Act). The proposed work also duplicates ongoing efforts by the Northwest Power Planning Council (Council) and the fish and wildlife agencies and tribes in developing system and subbasin models and represents significant competition for limited funds for research and other activities under the Council's Fish and Wildlife Program.

Mitigation and compensation measures under the Power Act are not required to satisfy a cost/benefit threshold. However, where there are several equally effective means of achieving the same sound biological objective, section 4(h)(6)(C) of the Power Act requires the use of the alternative with the minimum economic cost. Therefore the economic cost of alternatives must be determined in order to select the minimum cost alternative.

However, the proposed modeling described in the planning documents includes an assessment of cost-effectiveness tradeoffs rather than only directing the evaluation to the assessment of costs of equally effective alternatives. This assessment would include developing quantitative estimates of technical, legal (including treaty Indian fishing rights), institutional, political, and management constraints. We see no useful purpose in this exercise, and consider it inappropriate to attempt to translate constraints of this nature into a quantitative form.

The research planning documents also propose modeling the bio-economics of the ocean salmon fishery which would include estimates of consumer benefits, local income and employment, and how harvest is affected by various controls on fishing effort. Developing the capability to evaluate the inefficiencies of the ocean salmon fishery is not an analytical tool required by Bonneville to carry out its fiduciary responsibilities.

The Northwest Power Planning Council (Council) recently completed an exhaustive evaluation of the extent and causes of the loss of salmon and steelhead in the Basin and estimated the hydropower related losses. The Council solicited extensive public comment and established its interim goal of increasing adult runs by 2.5 million fish. The current emphasis of the Program is focusing on how to meet this goal. Your proposed Task 2, which would use models to analyze the nature and extent of the mitigation responsibility, duplicates the Council's recent action.

Modeling can be useful for identifying uncertainties, integrating information, identifying key variables that respond to management actions, and comparing the fish production implications of various actions. On the other hand, modeling can also be misused. The Corp's FISHPASS model, contrary to the characterization in your planning documents, is not widely accepted by the fish and wildlife agencies and tribes. The fish and wildlife agencies and tribes frequently have pointed out deficiencies of FISHPASS and objected to its use in estimating mainstem passage mortality. The FISHPASS model assumes that turbine and reservoir mortality are independent. The cumulative effect on reservoir mortality of fish passing through a series of turbines is not addressed by the model. The result is that the relative benefits of alternative means of avoiding turbine mortality estimated by FISHPASS may be substantially underestimated. Policy decisions by the Corps, Bonneville, and the Council have ignored this uncertainty.

While we support on-going modeling efforts, we are reserving judgment on the usefulness of modeling as a tool for policy/decision-making in the Columbia River Basin until the Council's model has been tested through system and subbasin planning. Meanwhile, your proposal to greatly expand the modeling effort in the Basin confounds this ongoing development and evaluation process and would compete for limited funding.

We appreciate the opportunity to provide comments.

Sincerely,

William S. Shake

Assistant Regional Director
Fishery Resources

cc: CBFWA

Yale University *New Haven, Connecticut 06511*

SCHOOL OF FORESTRY AND ENVIRONMENTAL STUDIES

Marsh Hall
360 Prospect Street
Telex: 5101012363 (Yale FES)

Dr. Allen Kneese
Resources for the Future
1616 P Street NW
Washington, D.C. 20036
April 20, 1988

Dear Dr. Kneese:

I have read with great interest the RFF document concerning the design of studies for development of BPA Fish and Wildlife Mitigation Accounting. The objective, to analyze the effectiveness of different fish mitigation strategies, is an important key to both environmental and development goals in the Pacific Northwest. From the environmental perspective, an analysis of the effectiveness of policy offers the chance of improving the environment, possibly obtaining more fish, by channeling resources to programs which work. From the development perspective, the more effective use of public dollars can only lead to a higher standard of living for all Northwest citizens.

For those who think it is unnecessary to examine the effectiveness of current mitigation policies, recent history provides a useful lesson. Until the mid seventies, fishery biologists in the Pacific Northwest were spending millions of dollars removing woody debris from streams in the region. Analysis of this policy has eventually shown that these expenditures not only did not increase fish production but they actually reduced fish stocks. Current policy entails efforts to increase woody debris in streams. Blanket refusals to carefully examine the effectiveness of mitigation plans cannot be made in the name of the environment.

The RFF emphasis on system design captures an important point. The success of any fishery action depends not only upon the immediate local impacts of a project but also upon the downriver system, the ocean, and the return visit. A particular investment may appear to be locally successful, for example, by releasing thousands of smolts into the river system. However, if all the smolts will die because of an impediment downriver, this investment will actually be a failure. RFF°s recognition of the interaction amongst the various components of the system is an important feature of their effort. It is critical that a system wide model of the migrating fishery be constructed for policy and research (although the level of detail needed in this model is a matter of debate).

As much as I agree with the need for planning and analysis, however, I do not totally agree with the system wide solution that RFF is promoting. I believe the RFF design has placed too much emphasis upon finding a single least cost solution to the entire system. This strikes me as a fragile and naive research approach. It is fragile in that it cannot work until all the parts are in place. Since the economic and biological system being modelled is complex and there are large gaps in our understanding, the model will not be ready for policy analysis for years (and possibly ever).

The single solution approach seems naive in that policy is being presented as though it simply were a matter of finding the least cost way of obtaining x number of total fish. This is naive because there are other important goals which will be demanded from the solution once the "leasct cost policy" becomes clear. For example, the least cost policy will probably identify upstream populations as expensive and will eliminate them. Citizens of Idaho and eastern Oregon and Washington may not care for this outcome. Similarly, certain species will probably be easier to introduce than others. No where in the least cost model is there a method to weigh the relative importance of different species. The size of the fish may also be important. It is clear in the Rocky Mountain recreation fisheries that size is paramount over numbers. Another component which must be developed is the reaction of Canadian and Alaskan fishermen to any increase stocks. Will the Northwest want to foot the bill to increase catch in other regions? None of these issues are addressed in a system wide least cost solution. A more flexible policy tool is needed.

Instead of a large system wide single solution, I would recommend a series of micro studies examining possible investments. For example, one could study increasing water flows during different months at each dam, building hatcheries, constructing artificial spawning beds below dams, etc. These micro studies would measure what these investments did to increase local smolt production, local fishery survival rates, etc. These local changes could then be entered into a system wide model to see how these local changes would translate into changes in desired outputs such as catch rates. Using these measures of output and the costs of each project, individual projects could be ranked against each other. Ineffective projects could be abandoned in favor of projects which really made a difference to the fishery. Projects which serve other goals can be examined in terms of how much they increase costs. This micro approach has the advantage that it reflects the relevant economic information and yet keeps the tool simple enough that policy analysts can explore different solutions. In contrast, a system wide least cost approach may be technically correct but it will certainly be inaccessible to all but a few technicians. The micro approach has the additional advantage that results are available before the entire project is completed. Thus, key projects can be examined first for early assessment.

A second major point where I feel the RFF proposal has strayed awry concerns the need for empirical studies in order to complete this effort. The RFF proposal seems to imply that we have this empirical information at hand, it simply has not been put together. My initial research into combining fishery science and policy suggests that this is not the case. Key links between management actions and fishery results remain uncertain. As long as this remains, the simulation model will be helpless. A simulation model whose parameters cannot be justified by empirical data is a tool waiting for abuse. Too often in systems analysis, when a link is not understood, it is "simulated". Volumes II and III of the RFF report are good examples. They give the illusion of being answers when in fact they are just hypothetical examples.

Simulations only work if they are backed by solid empirical research. One important role of developing a logical structure to analyze fishery mitigation policies is to establish priorities for fishery research by identifying gaps in our knowledge linking policy actions to desired outcomes. Coordinated funding for biological and economic research must then attack these gaps. It is only through targeted empirical biological research, that the key links of the model will be measurable. What is needed is not a simulation game but rather a carefully designed and immediate program for economic and biological empirical research.

Despite these reservations concerning the specifics of the RFF plan, I wholeheartedly support the thrust of what they are doing. It is critical to review whether or not the mitigation program is doing what it is supposed to do. Money spent on the environment is a scarce resource. It should not be wasted.

Sincerely,

Robert Mendelsohn

APPENDIX C

Phase II Personnel and their Main Contributions to the Final Report

This list follows the order in which the individual's contributions appear in Volume 2: Technical Reports.

Danny C. Lee, Research Associate, Resources for the Future, Washington, DC	Part I
Clifford S. Russell, Director, Vanderbilt Inst. of Public Policy Studies, Vanderbilt University, Nashville, TN	Part I: Chapter 8
Charles M. Paulsen, Chief, Computer Services, Resources for the Future, Washington, DC	Part II
Walter O. Spofford, Jr., Senior Fellow, Resources for the Future, Washington, DC	Part II: Chp. 1-4, 6
Susan A. Capalbo, Professor of Economics, Montana State University, Bozeman, MT	Part II: Chapter 5
Virgil J. Norton, Director, Division of Resource Management, West Virginia University, Morgantown, WV	Part III
Allen V. Kneese, Senior Fellow, Resources for the Future, Washington, DC	General planning and coordination of research project